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# TROPICAL AGRICULTURE

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# An Army routed

In the sun-soaked lands of the Rhodesias, maize is a staple food. It is also a favourite target of the voracious army worm—caterpillar of the moth *Laphygma exempta*. The army worm, so called because of its vast numbers, appears suddenly, unexpectedly and devastatingly. It comes like a thief in the night and in a few short hours can destroy every young and promising plant in its path .... pasture, forage grass or cereal. For generations, when the army worm struck, hunger came close. Today, however, the army worm has been routed—and the livelihood of millions protected. Tests have conclusively proved that even when followed by heavy and continuous rain, a complete kill of the army worm can be obtained by a dilution of endrin 19.5% emulsifiable concentrate applied by knapsack sprayer.

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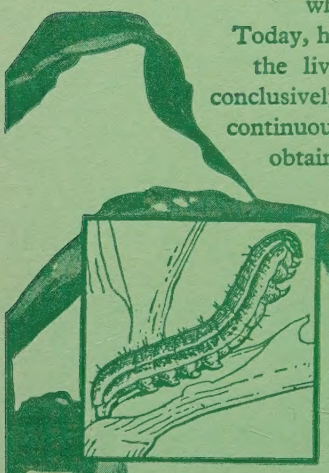

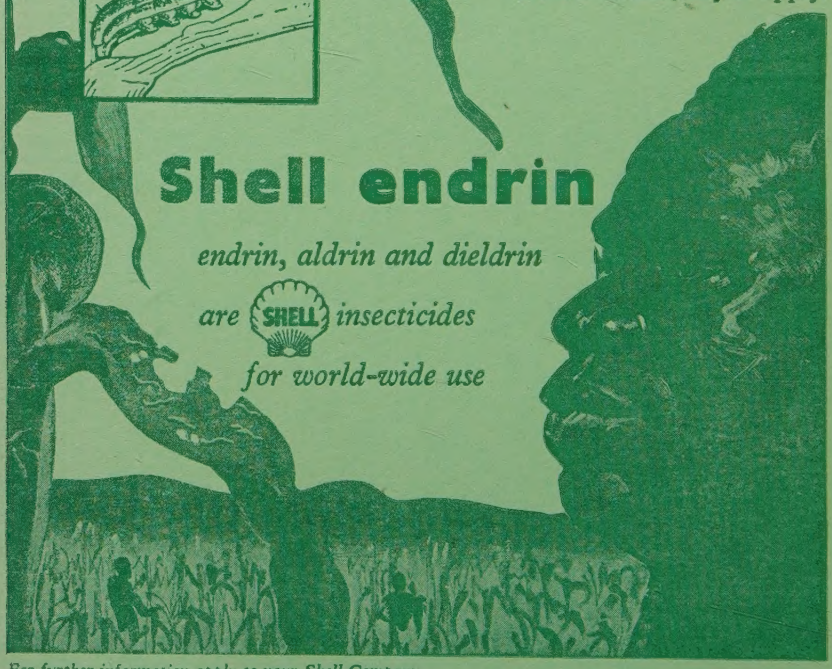

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# *Editorial*

*Imperial College of Tropical Agriculture Reunion*
*London 1957*

The sixth annual reunion will be held at the Overseas League, Park Place, St James St, S.W.1, from 6 p.m. to 8 p.m. on Friday, 19th July. Bar optional. Tickets (5*s* each) should be obtained in advance from: the Honorary Secretary, I.C.T.A. Reunion, c/o West India Committee, 40 Norfolk St, London, W.C.2.

# *The Nature of Tropical Rainfall*

R. P. Beckinsale

*Senior Lecturer in Geography, University of Oxford*

The inherent and inseparable combination of properties that underlie the fundamental character of tropical rainfall is not well understood and, in spite of the publication of a vast new literature on the topic, the pitfalls awaiting its would-be summarizer are many.

The literature approaches the problem from so many different angles that it is often difficult to reconcile the findings or, at least, to recognize in such diverse language the possibility of similar conclusions. The network of simple climatic statistics is improving in density but the vital meteorological observations are still in their infancy. Hence the following summary can do little more than provide the excuse for the addition of a short up-to-date bibliography.

## THE TROPICAL ARENA

### *Relative vastness*

When in 1569, Gerard Mercator devised his famous cylindrical world projection he delivered unwittingly a stunning blow to tropical meteorology. Seldom again was the true relative size of the Tropics to be realized, least of all by the general public. A projection, ideal for showing direction but hopeless for showing relative areal distributions except near the Equator, was henceforth all too frequently to mask the fact that the globe outside latitudes 40° N and 40° S is a mere appendix—or rather two mere appendices—to a vast tropical belt (*Table 1*).

*Table 1. Zonal distribution of land and water*

| *Lat.* | *Earth's surface* % | *Approx. area* $km^2 \times 10^6$ | *N Hemisphere* | | *S Hemisphere* | |
|---|---|---|---|---|---|---|
| | | | *Water* % | *Land* % | *Water* % | *Land* % |
| 0°– 5° | 8·68 | 2×22·124 | 79 | 21 | 76 | 24 |
| 5°–10° | 8·62 | 21·96 | 76 | 24 | 77 | 23 |
| 10°–15° | 8·48 | 21·633 | 76 | 24 | 80 | 20 |
| 15°–20° | 8·30 | 21·145 | 71 | 29 | 76 | 24 |
| 20°–25° | 8·04 | 20·499 | 65 | 35 | 75 | 25 |
| 25°–30° | 7·72 | 19·699 | 60 | 40 | 78 | 22 |
| 30°–35° | 7·36 | 18·749 | 58 | 42 | 84 | 16 |
| 35°–40° | 6·92 | 17·656 | 57 | 43 | 93 | 7 |
| *Total* | 64·12 | 163·465 | 68 | 32 | 80 | 20 |

It should, however, be realised that this areal concept is itself a gross understatement of tropical vastness from a meteorological point of view. The thickness of the troposphere over the Equator, as judged by the mean height of the base of the stratosphere, is about 11 or 12 miles and does not decrease appreciably within the tropics. At some zone in the sub-tropics the

base of the stratosphere drops rapidly to seven miles or less and thence on an average lowers poleward (*Figure 1*). In other words, without entering into volumetric niceties, we may assume that by far the bulk of the world's troposphere lies over the ' tropics ' and that poleward of the tropical zone the troposphere consists of two relatively shallow appendices, one to north and one to south. The latter impinge upon the poleward edges of the tropical ' belt ' but they are quite separated from each other by it.

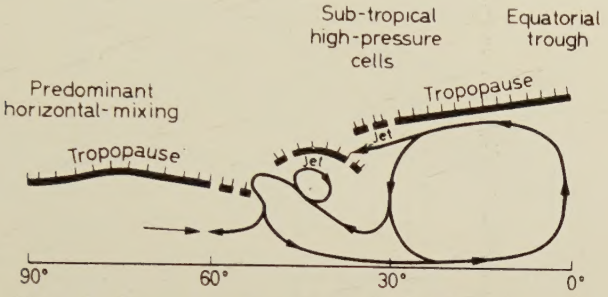



*Figure 1. Scheme for mean meridional circulation in winter (after Palmén). The Polar front, which migrates vast distances, is omitted*

*Astronomical factors*

At least two astronomical aspects belong peculiarly to tropical meteorology: the sun is always overhead somewhere in the Tropics and its noon altitude, and consequently the possible insolation, is high all the year; the overhead position of the noonday sun migrates from Tropic to Tropic, an earthly distance of over 3000 miles.

As regards the second, or migrational factor, it is important to notice that the actual rate of migration of the position of the noon overhead sun is very unequal, being relatively fast near the Equator and relatively slow at the Tropic (*solstice*). For this reason the periods of overhead sun or sun-baking also differ greatly. The Equator has two relatively short periods; each Tropic has one long period annually. Thus, in practice, it can never become really hot at the Equator whereas athwart either Tropic the longer daylight and prolonged successive period of overhead or nearly overhead sun in summer permit the generation of excessive heat (*Figure 2*).

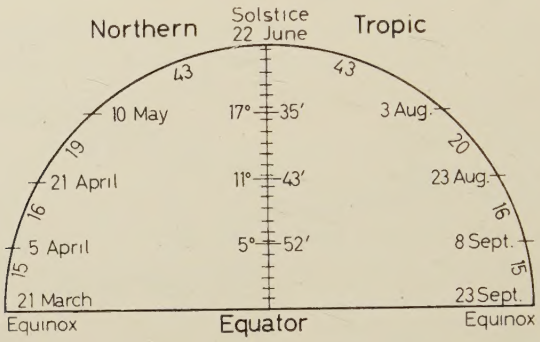
It may also be noticed that ideally on a featureless globe the rainy season would follow the thermal equator which in turn would follow, with a reasonable lag, the overhead sun. In reality many other factors upset this simple scheme but none the less most stations near the Tropic do experience a rainfall maximum in summer and not a few near the Equator show some form of double rainfall maximum.

*Global dynamic influences*

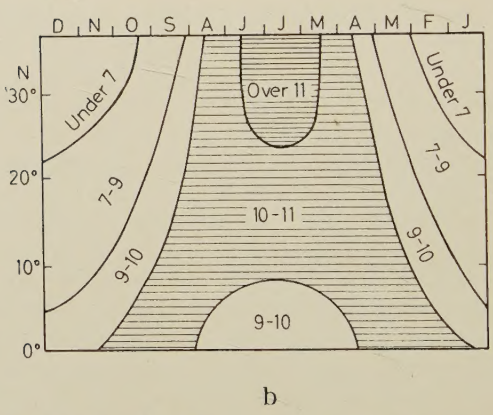
Some of the global dynamic aspects of tropical meteorology cannot be explained satisfactorily in simple language and a few defy analysis in any form. Fortunately only two major dynamic topics concern us here.

First, the Coriolis force, or deflective influence of the earth's rotation, is practically negligible athwart the Equator and is not of great relative

importance anywhere within about 20° latitude of it. In other words, in the absence of severe surface friction, winds will tend to blow almost directly toward low pressures and a small change of pressure will tend to cause a strong wind. Differential thermal heating will soon create an appreciable air-movement; for example, land-and-sea breezes will tend to be vigorous over a relatively long distance.




a




b

*Figure 2. Rate and effect of migration of overhead sun.* a, *On about dates given the sun is overhead at its quarter-way stages. Numbers on circumference give days taken for each quarter-way stage.* b, *represents duration of sun-baking period. Numbers show relative solar energy received per unit of horizontal surface if there were no atmosphere. In June, if cloudiness and turbidity are considered, the proportion between actual insolation at Equator and 30° N is about 2:3 so that above diagram rather understates the relative strength of the sun-baking period near the Tropic*

Second, the influence of the earth's rotation on air outflowing at high levels in the troposphere over the meteorological equator seems primarily responsible for descending air-masses in the sub-tropics. This dynamic set-up is represented at the earth's surface by high-pressure ' cells ' which wax and wane but which are as a rule present in the regions of latitudes 30° N and 30° S, especially over the oceans. The general latitudinal position of these sub-tropical anticyclones migrates to a small extent with

the migration of the equatorial trough. Like it these are by no means continuous round the globe but rather are regional and quasi-permanent in nature. They are, generally speaking, associated with clear skies and low rainfall and also peculiarly associated with the ' Trades ' and the trade-wind ' inversion '.

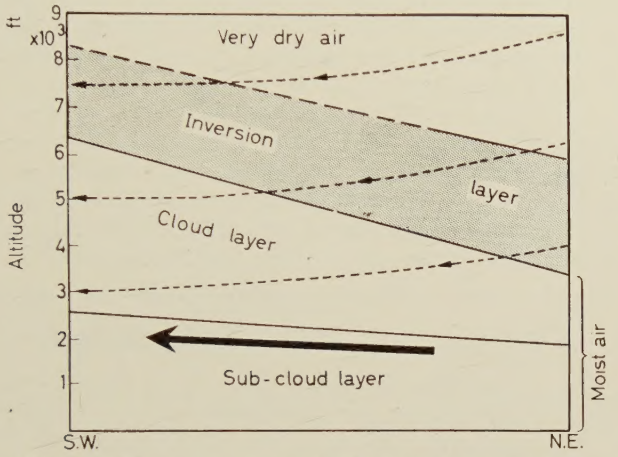



*Figure 3. Schematic cross-section of NE Trades over Pacific between 32° N, 136° W and 21° N, 158° W (Honolulu). Large arrow shows main airflow; arrows on dotted lines indicate general subsidence of air-mass through the inversion layer (after Riehl, Yeh, Malkus and La Seur)*

The Trades are remarkable for their constancy, shallowness and stability. The last-named quality is all the more notable as the winds, or air-masses, originate over the ocean and contain plenty of moisture as is shown by the heavy rainfall where convergence occurs and where mountains cause ascent as in Hawaii. The fair weather of the undisturbed Trades arises largely from the presence of an inversion layer of subsiding air which overlies the surface wind (*Figure 3*). This trade-wind inversion has been called by H. RIEHL[1] ' perhaps the most important regulating valve of the general circulation '. As regards rainfall, no other major air-mass has a comparable effect since, except where convergence prevails locally, in flat areas low rainfall predominates beneath it.

The main sources of the subsiding air seem to be the eastern parts of the sub-tropical anticyclonic cells, which happen to overlie areas of relatively cool ocean and especially those where cold water upwells off the coast. In these areas subsidence of air is strongest and the base of the inversion-layer lowest, often descending regionally to well under 2000 ft. But towards the Equator and west of these so-called ' root ' areas the inversion layer subsides less effectively and, no doubt partly due to the nuzzling action of the tops of cumuli clouds, its base rises usually to 8000 ft or more near the equatorial trough.

The tremendous oceanic areas affected by ' constant ' trades wax and wane in conjunction with the other main features of the general tropical circulation. The surface tracts experiencing strong persistent trades vary

from about 30 million square miles in March to about 40 million square miles in July. The changes in size and location are, however, due less to north-south migrations than to a great westward advance of the systems during the cool season and a strong withdrawal eastward, or landward toward their ' roots ', in summer[2,3].

It is obvious that rainfall is likely to be lowest on the eastern sides of the subtropical anticyclonic cells (the ' roots ' of the trades) whereas on their western and equatorward edges there is a possibility of rainfall in at least one season.

## REGIONAL FACTORS

### *Distribution of land and sea*

Much of the nature of climate at ground-level depends on whether the surface is land or water. There is little need to emphasize the tremendous preponderance of oceans in tropical latitudes but the asymmetry of the distribution of land-masses on either side of the Equator is often overlooked.

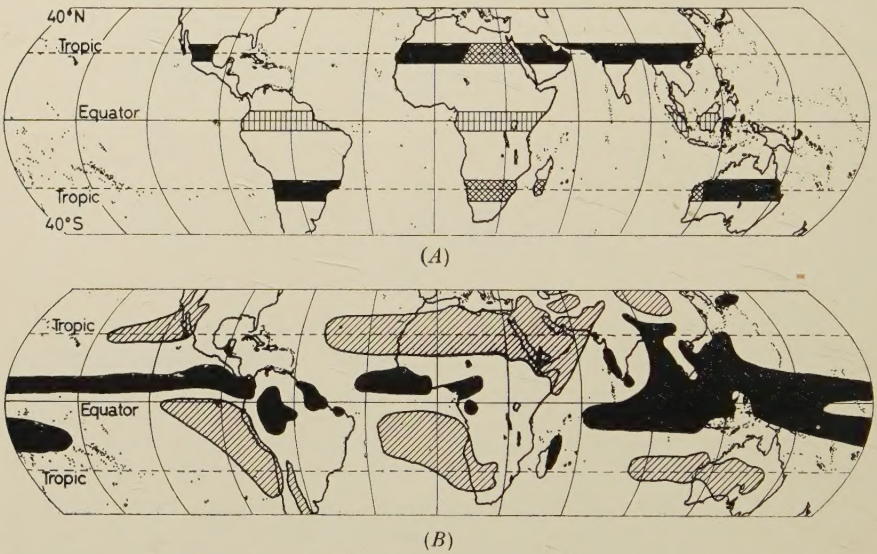



*Figure 4. A, the relative position of land-masses athwart the Tropics and the Equator. Black denotes no meridional overlap of land at the opposing Tropic. B, general distribution of wet areas (black: over about 80 in. precipitation annually) and dry areas (shaded: under about 10 in. precipitation annually) in the tropics*

The Equator crosses land in only about 5800 miles of its 25,000-mile circuit but far more striking is the asymmetrical positioning of land-masses on the Tropic where in a circumference of about 22,500 miles land opposes land in the other hemisphere over a distance of only about 2500 miles (*Figure 4A*). The whole lay-out could hardly be more sea-bound and more disposed to the generation of monsoons.

It is presumably the greater land surface of the northern hemisphere that causes the thermal equator and the ' equatorial trough ' (doldrums) to lie, as a rule, well north of the geographical equator. The mean position of the ' equatorial trough ' is about 5° N but its seasonal migrations vary greatly

and may amount to 25° of latitude in some regions. It is perhaps unwise to mention the *mean* position of any meteorological feature in the tropics but it is vital to any discussion that the geographical equator should not be confused with the thermal equator. The latter migrates vast distances and, unlike the Equator, seems to have a certain symmetry of general meteorological conditions associated with it; it has, moreover, no strict circumferential continuity, being rather a discontinuous alignment from a global point of view.

There is still general agreement that the differential heating of continents and oceans is the primary cause of monsoons. The sea-monsoon, due to the abnormal heating of low-lying land-masses during the sun-baking period near the Tropic, is an important feature of surface air-mass movement during the summer within the tropical belt. The sea- or summer-monsoon is a great rain-bringer as in West Africa and much of south-eastern Asia. Whether there is an appreciable land-monsoon in the Tropics, except in the China Seas, is a more difficult matter to assume.

## REGIONAL AND LOCAL FACTORS

### *Ocean currents*

The effect of ocean currents need not concern us long as they are mainly dependent on climatic circulations. Near the Equator the surface movement is zonal and a large-scale transference of warm water from east to west gives exceptionally warm seas on the western sides of oceans. Where the currents flow in a markedly meridional direction as happens nearer the Tropic there are relatively warm waters moving poleward in the western parts of oceans and cool currents flowing equatorward in the eastern parts. The latter are associated with cold upwellings offshore and are important as they exert a strong influence on local sea-breezes. The relatively cold water encourages the generation of vigorous sea-breezes which carry inland the low cloud or fog which, in the presence of a low inversion-layer (p. 79), forms readily over the sea. The trade-wind inversion layer may at times be as low as 200 ft and very rarely descends virtually to sea-level. However, fog thus formed is quickly re-evaporated on passing inland and although it dampens surfaces, rainfall is seldom recorded. Thus these cool-current littorals at the ' roots ' of the trades and on the extreme lee-side of land-masses are the driest lands on the earth. In spite of fog, mist and heavy dew, Iquique (Chile) and Walvis Bay (SW Africa) have practically no rainfall while large seaboard strips here and in NW Africa and in parts of southern California have under 5 in. of rainfall in an average year.

### *Differential heating of land and sea*

In the absence or practical absence of Coriolis force, the differential heating of land and sea within the tropics causes breezes which persist over relatively great distances. On flat coasts a strip 30 to 60 miles wide may benefit from the sea-breeze, which blows after sunrise. Under very favourable conditions the breeze has extended 80 miles inland locally and has been known to reach storm intensity during its onset. In Jakarta, it occurs on about 75 per cent of days in the dry season and on over 80 per cent in the wet season; on desert coasts it may occur almost every day during the hotter months.

The frequency of sea-breezes will be obscured, or strengthened as the case may be, when there is a strong on-shore monsoon or trade, while at such times the land-breeze, which develops at night, may be lessened or entirely obviated.

But the formation of land- and sea-breezes is not easily discouraged. It often happens that when the main air-movement aloft is contrary in direction to that of either the land- or of the sea-breeze, the onset of the breeze may be delayed several hours and may take the form of ' a line-squall oriented parallel to the coast '. The relatively cold air of either breeze then undercuts the warmer adjacent air and, especially where concave curvatures of the coastline favour convergence of surface winds, may often form vigorous ' line-squalls and convective phenomena '[4].

*Surface relief*

Tropical slopes, for climatic and often also for tectonic or structural reasons, are usually relatively steep. The speed and intensity of surface-wash on steep slopes maintain a high gradient as the slopes retreat and the sharp relief in its turn intensifies the rainfall. Moving air-masses obstructed by such slopes tend to ascend abruptly and the rainfall tends to be correspondingly heavy. The nature of air-flow over and around mountains is extremely complicated (pp. 95–6) yet certain simple climatic considerations may be attempted here.

The rate of increase of annual precipitation with ascent up exposed hillsides in Britain averages about 1 to 2 in. per 100 ft in the drier south east and 3 to 4 in. in the wetter west. It is perhaps surprising to find that the mean rate of annual increase with relief-height throughout much of the tropics is no greater than on Snowdon or Ben Nevis. To use an oft-quoted example of the ' tremendous rainfall increase caused by relief ' we may discuss Mahabaleshwar, at 4540 ft near the exposed crest of the Western Ghats. Here in July the average rainfall exceeds 100 in. and nearly every day is wet. The annual average is 261 in. But as the adjacent coastal plain receives about 40 in. in July and about 80 in. or more in the whole year, the increase of annual precipitation per 100 ft of ascent is about 4 in.

Yet in the tropics there are localities with quite astonishing relief-rain increases. In parts of Assam the mean rate of annual increase must often exceed 10 in. per 100 ft and must in wet years be nearly double that amount; in the Hawaiian group, where small mountainous tracts of all the islands except Lanai experience average annual falls of over 320 in., the mean rate of increase must often exceed 8 or 10 in. per 100 ft. But these localities have quite exceptional rain-making qualities apart from mere obstruction: in some, air-mass convergence, topographical and/or dynamic; in others, a strong regional air-movement is often deeply disturbed by local perturbations such as ' high-island ' thermal pulsations (p. 83) and by tropical cyclones.

It is, however, important to notice that the rate of increase of rainfall with relief *throughout* the wetter tropics would be amazing or still more amazing were it not for the astonishingly high rainfalls on lowlands and at sea-level. To this matter we will return later.

There are many other features of much climatic interest in the influence of

relief on precipitation. First; the highest peaks and ridges have a zone of maximum annual rainfall above which precipitation tends to decrease. In regions that come under the influence of the equatorial trough or of moist air-masses for all or much of the year the rainfall may increase or not decrease appreciably up to a considerable height. In Java the decrease becomes marked and steady only above about 5000 ft but the zone of maximum rainfall varies with the total height of the local mountain slope and tends to occur about half-way up it. In the Hawaiian Islands peaks below 7000 ft tend to have maximum rainfalls just beyond or on the summits but the highest peaks which penetrate the trade-wind inversion are arid at their tops and the zone of maximum rainfall ( > 320 in.) lies at about 3000 ft on their wettest slopes. The obvious conclusion is that, as would be expected, orographic precipitation is mainly a function of the nature of the air-mass and of the shape and size of the *whole* relief obstacle. It is, however, pleasant to notice that the classical model—the cloud-layer or rain-belt encircling the upper slopes of Teneriffe in Gran Canaria—remains secure for mountains penetrating the strong inversion-layer over areas at the ' roots ' of the Trades.

Second; in those large areas of the tropics where relief obstructs moisture-laden air-masses moving constantly from one direction during one season or all the year, the rain-shadows become quite excessive. Decreases in average annual rainfall of 200 in. or even 300 in. within a horizontal distance of a few miles are known and demonstrate the frequency of subsiding air-flow in the lee of mountains.

Third; mountainous regions have another vital influence on air-masses in addition to their obstructional effect. Mountainous or hilly relief will, especially in the absence of strong prevailing winds, tend to create its own air-circulation in the form of a diurnal pulsation of mountain- and valley-breezes. The up-slope or valley-breeze forms by day and is capable of causing convective thunderstorms at high levels day after day in fairly calm weather; the down-slope or mountain-breeze operates after sunset and, although much impeded by surface friction in wooded areas, may become strong, especially where canalized into valleys. The latter may reinforce the land-breeze off tropical coasts and cause it to become vigorous and gusty, just as the former (the up-slope wind) frequently reinforces the sea-breeze. Thus the diurnal pulsation of tropical littorals and tropical islands is a complex combination of various powerful factors. The ' orographic-cell ' of Puerto Rico is shown for a day-time condition in *Figure 5*. It should be noticed, however, that mountain- and valley-breezes tend to blow wherever great differences of relief occur and that peaks surmounting high inland plateaux are liable to afternoon thunderstorms.

*Nature of ground cover*

Of the direct physical influence of vegetation cover on rainfall in the tropics little long-term information is available*. Yet it seems reasonable to assume that a coastal forest fringe, 150 ft or more high, would cause, by obstruction and turbulence, a marked increase of rainfall from moist air-masses moving inland. Such an effect seems to be partly responsible for the heavy rainfall on the lowlands at the mouth of the Amazon.

* For details of eco- or micro-climatology, see P. W. Richards[5] and E. Bernard[6].

Concerning the influence on air-masses of vast expanses of tropical evergreen forest, we may perhaps assume that the high average relative humidity of the forest tends to conserve the moisture-content of air in contact with it. Indeed, the distribution of heavy rainfall in inland Brazil

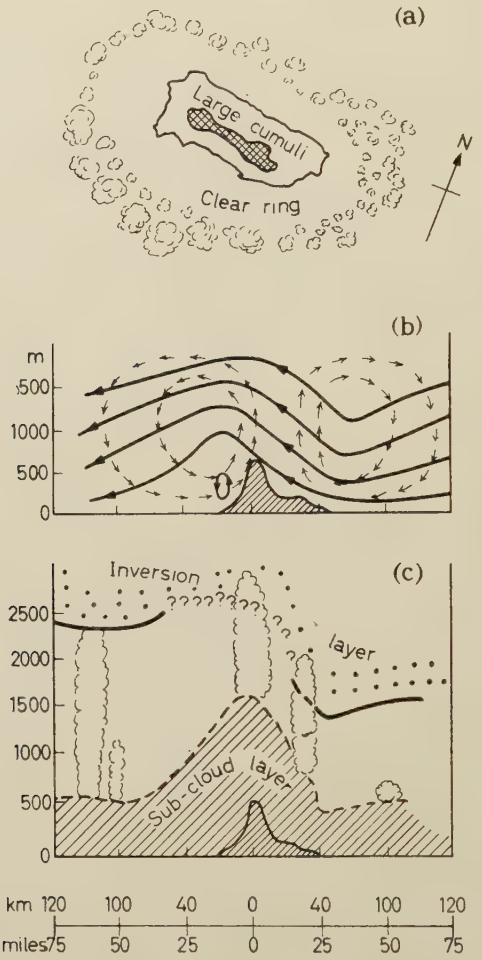



*Figure 5. Schematic reconstruction of day-time orographic-convection cell of trade-wind island (Puerto Rico). Showing ascent over island and subsidence in a surrounding ring on 25 June, 1952 (after Malkus). In* a *cross-hatching denotes land over 2000 ft; in* b *streamlines of main airflow are shown in thick lines and of local convection cell in thin lines; in* c *the inversion layer was not measured in parts*

and the remarkably high humidity of Atlantic air-masses invading East Africa from over the Congo basin suggest that there is an ' Equatorial rain-forest air-mass ' very similar to the ' Equatorial air-mass ' proper.

DISTRIBUTION OF ANNUAL RAINFALL

*Latitudinal*—On the globe the mean annual rainfall per latitude is highest (about 75 in.) in approximately 5° N and, if the frigid polar zones are ignored, is lowest (30 in.) in latitudes 25° to 30°. The average annual rainfall of the belt within 10° of the Equator is about 65 in. whereas that of the two belts of latitude 10° to 20° is about 45 in. and of latitude 20° to 30° only about 33 in. (*Figure 6*). Of the world's total precipitation over one-half falls within the tropics while about two-thirds occur equatorward of 30° latitude. Yet Riehl remarks (ref. 1 p. 74) that the world rainfall ' is not concentrated in quite such overwhelming measure in the tropics as one might have thought '.

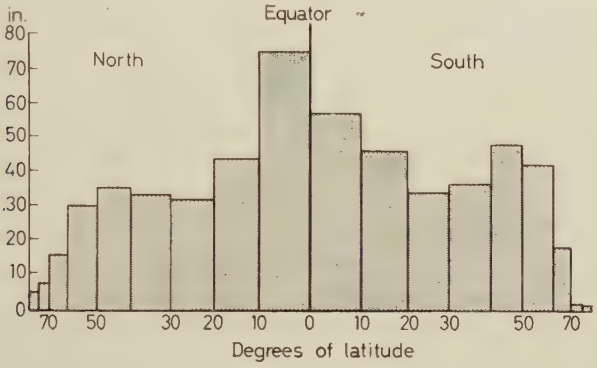



*Figure 6. Zonal distribution of mean annual precipitation*

*Regional* —The regional distribution of mean annual rainfall is too familiar to need discussion. Attention, however, may be drawn to the wettest and driest regions, with over 80 in. and under 10 in. respectively (*Figure 4B*).

A belt of exceptional wetness stretches unbroken for over 14,000 miles from near the Seychelles in the Indian Ocean eastward to the Gulf of Panama. The Andean cordillera intervenes between this belt and the areas of heavy rainfall in Amazonia and nearer the Caribbean. There is a long stretch of lower rainfall over the western Atlantic before the precipitation increases again off and upon the coast of West Africa and the Gulf of Guinea. It will be seen that these large excessive rain-areas are, apart from Amazonia, essentially oceanic and that the African plateau forms the greatest gap in their continuity.

The rainiest belts, as P. R. Crowe has demonstrated, are those where the equatorial trough lingers or oscillates backwards and forwards during much of the year. The outlying rainy areas are associated peculiarly with orographic factors.

The dry regions of the tropics are equally remarkable for their vastness and for their rainfall amounts but in this instance for their striking insignificance. Apart from the Sahara and various smaller land-deserts, the regions of low rainfall lie mainly over the seas leeward of continents. The land-deserts arise from many climatological causes—such as continentality,

leeward situations and so on; the sea-deserts are swept by persistent trades with a strong inversion-layer although other conditions such as cool seas also favour drought. These sea-deserts show a strong coincidence with the ' roots ' of the Trades and with the eastern ends of anticyclonic cells.

From a climatological point of view at least, it is regrettable that these great oceanic deserts are so often ignored. In fact, it should be stressed that the Sahara is almost repeated again over the Atlantic and that littoral deserts, such as the Kalahari and Atacama, are merely the land fringes of tremendous deserts which brood with unremitting intensity over the adjacent oceans (*Figure 4B*).

## SEASONAL DISTRIBUTION OF RAINFALL

The rainfall régimes of many tropical localities have been described in great detail but there seems to be no ' common denominator ' which permits their simple classification. For the non-arid tropics, climatologists favour W. Köppen's quantitative divisions, based on the mean rainfall of the driest month, into:

*Af*—tropical rain-forest, with no month below 2·4 in. mean rainfall;

*Aw*—tropical savanna, with one or more months below 2·4 in. mean rainfall;

*Am—mittelform* or intermediate (often monsoon) where a large annual rainfall can offset a dry period.

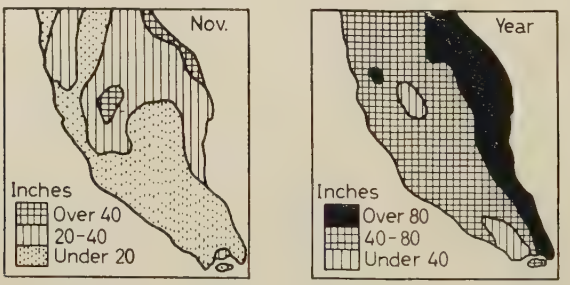



*Figure 7. Range of rainfall in recent years in Malaya. Longer records would probably show that all the eastern half of Malaya has an extreme annual range of well over 80 in. (after Watts)*

In the *Aw* and *Am* groups the rains tend to come mainly in summer although considerable differences in régime can occur and autumn is often the rainiest season (as at Campinas, see *Figures 9* and *10*). But in climates with rainfall all the year (*Af*), the régimes are quite individual and even in the same region no two stations seem to have exactly the same régime. Yap Island and many wet stations in the West Pacific have a summer maximum of rainfall; the Hawaiian group in the eastern Pacific has a winter maximum except in some leeward locations where summer is rainier. There seems little point in amplifying the statistics in *Table 2* (of rainfall in inches), selected at random from sea-level stations within the northern tropics.

*Table 2*

| *Station* | J. | F. | M. | A. | M. | J. | Jy. | A. | S. | O. | N. | D. | *Yearly total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Georgetown* | 7·9 | 4·6 | 7·2 | 6·0 | *11·1* | *11·7* | 9·9 | 6·5 | 3·1 | 2·9 | 6·7 | *11·1* | 88·7 |
| *Singapore* | *9·9* | 6·6 | 7·4 | 7·6 | 6·7 | 6·8 | 6·8 | 7·9 | 6·8 | 8·1 | *9·9* | *10·6* | 95·1 |
| *Akassa* | 2·6 | 6·5 | 10·0 | 8·6 | 17·0 | 18·6 | 10·1 | 9·3 | *19·3* | *24·7* | 10·6 | 6·5 | 143·8 |
| *Yap* | 6·0 | 4·8 | 5·5 | 7·0 | 9·9 | 8·8 | *16·0* | *16·1* | *15·8* | 14·7 | 11·2 | 10·3 | 126·1 |

The meteorological basis is equally varied. Some regions with rainfall all the year may be affected by the equatorial trough at two or more seasons; some have strong onshore prevailing winds for most of the year; others have a combination of the above together with powerful local factors.

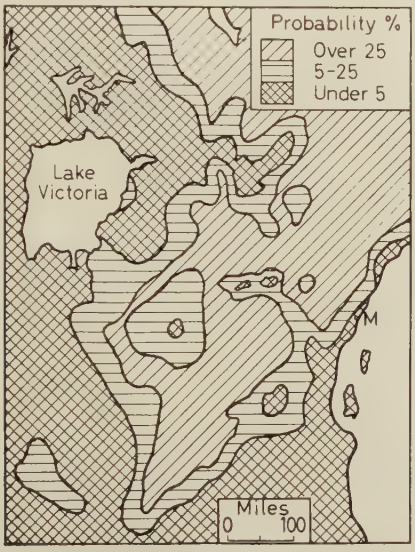



*Figure 8. The probability of less than 20 in. of rain annually in parts of East Africa (after Glover, Robinson and Henderson)*

The desire to group together apparently similar results arising from a wide diversity of causes seems inherent in educational methods. But the small value of simple climatic classifications in the non-arid tropics has always been realised by ecologists. The present empirical or quantitative subdivisions were meant to coincide with the distribution of major ' natural vegetation ' types. There is, however, strong disagreement today on the basal causes of these ' types '. Richards considers that the savanna was probably ' never a climatic climax ' but rather biotic or edaphic. ' The climatic limit between rain forest and savanna need not therefore be considered. The boundary between rain forest and deciduous forest on the other hand is a true climatic limit . . . this is mainly determined by seasonal drought . . .' (ref. 5 p. 152).

More recent attempts to classify climates by the use of elaborate combinations of factors, such as evapotranspiration, actual and potential, are of great value to ecologists, especially if the latter can agree on the amount of

soil-moisture storage available to tall trees*. But for climatologists the more complex the bases the more numerous become the divisions and the slightly dissimilar régimes of wet climates will probably never be differentiated. In other words, a would-be settler will know what he can grow but will have to study the rainfall régime independently. This, however, is perhaps the ideal solution as, owing to the extraordinary power of local factors, the rainfall régime of each locality in the wetter tropics must be studied on its own merits.

## NATURE OF RAINFALL

### *Intensity*

The large annual and seasonal rainfalls of the wettest tropical stations are not equalled in temperate latitudes where a mean of over 180 in. is rare. But for duration of rain and number of rain-days the rainy tropics do not exceed exposed maritime tracts in the westerly cyclonic belt.

Information on rainfall-hours seems very scanty. In Britain the mean duration varies from about 500 hr in East Anglia, to 800 hr or more in the uplands of the exposed west and to over 1500 hr in the rainiest parts of the Scottish Highlands. At Jakarta (71 in. annual rainfall: 138 rain-days) the duration is 360 hr. Presumably 700 hr or 800 hr (on an average about 2 hr a day) would be a high figure even for the wettest areas of the tropics.

On the other hand, rain-days are well documented. Only in the wettest parts of the tropics do the rain-days reach 200 to 250 a year, an average common in the most exposed tracts of the west of the British Isles. Over large areas of the wetter tropics the annual rainfalls may amount to as much as 130 in. but the mean number of rain-days may not exceed 200. For example, Pontianak in North Borneo averages 126 in. and 182 rain-days annually; Singapore 95 in. and 179 rain-days; and Menado in the Celebes 104 in. and 164 rain-days.

Areas with a marked dry season—and even some without it, for example Jakarta—have relatively few rain-days although they may have high annual rainfalls. Port Blair (118 in.: 139 rain-days); Rangoon (100 in.: 122 rain-days); Tahiti (72 in.: 130 rain-days); Bombay (71 in.: 75 rain-days); and Madras (51 in.: 57 rain-days) are typical of large tracts and may be contrasted in this respect with London (24 in.: 167 rain-days).

It is unnecessary to demonstrate that the *mean* precipitation per rain-day in the tropics is commonly $\frac{1}{2}$ to $\frac{3}{4}$ in. or more. Yet it happens that this intensity does not do justice to the ferocity of tropical rainstorms. At most stations the bulk of the precipitation comes from a few relatively severe 'rainstorms' or rain-spells which may last for more than one day. On Oahu, over a ten-year period, about 24 rainstorms occurred annually and of these ten provided over two-thirds of the annual precipitation[1].

The intensity of these tropical rainstorms is amazing†. In the wetter tropics generally local falls of 2 to $2\frac{1}{2}$ in. in 1 hr can be expected on an average once in two years. The maximum falls in 1 hr recorded in Java and at Singapore are 3·7 in. and 4·73 in. respectively.

* Whether, for example, 4 in. for grass and 12 in. for tropical rain-forest.

† For world's highest observed rates of rainfall over smaller time intervals see N. J. Jennings[7].

Daily falls of 6 to 8 in. are to be expected locally in one year out of two throughout the wetter tropics[8]. In Malaya over 10 in. in a day are recorded occasionally and up to nearly 20 in. very rarely. The heaviest daily fall yet recorded in the East Indies is just over 20 in. But these deluges are far exceeded in areas where strong winds thrust moisture-laden air masses up steep hill-slopes. In such localities, which happen to be quite widespread, 15 in. a day are not uncommon, over 20 in. occur occasionally, over 30 in. rarely and over 40 in. a few times in a century. The highest recorded falls in 24 hr are at Baguio (46 in.), at Cherrapunji (40·8 in.) and at Funkiko (40·7 in.).

If the records covering longer periods are consulted the amount of water that can be precipitated becomes still more astonishing: over 60 in. in 2 days, and from 80 to over 100 in. in 4 consecutive days. In August, 1841 Cherrapunji received 241 in. of rain, of which 150 in. fell on 5 consecutive days. The sheer physical effect of such downpours needs no embroidering. Flat areas are quite submerged and on steep slopes, where the soil-cover always seems so thin, rain-sodden lubricated masses may slip downhill, trees and all.

The more brutal side of the rainfall should perhaps not allow us to overlook the fact that its intensity or brief duration favours a fair amount of sunshine. It seems that most tropical rain-forest areas, outside the forest shade, have 40 to 55 per cent of the possible sunshine and that an average of 6 hr/day as at Singapore (6·1 hr) and Georgetown (6·8 hr) is not unusual at sea-level*.

In spite of what is written above, there are some localities in the tropics which have frequent small showers. On central Oahu 40 to 60 per cent of all rain-days gave short showers only; here the Koolau Mountains at 3000 ft have showers almost daily in the trade-wind weather and stations with annual totals of 140 in. have over 250 rain-days. These showers contribute relatively little to the annual total (ref. 1 p. 88). Green Mountain on Ascension Island (2200 ft) has numerous light nocturnal showers and a mean total rainfall of only 26 in.

At some stations the Trades deposit a heavy drizzle. Thus on the eastern escarpment of Madagascar at Tamatave a heavy drizzle prevails during much of the year, and especially towards the onset of the dry season. The rainfall readings, however, show only 180 rain-days and 120 in. in the mean year.

These occurrences of drizzle seem connected with the cloud-layer of the Trades, just as the small showers—which often consist of a few very big drops—are presumably associated with ' orographic cells ' and with precipitation from ' warm-clouds ' of moderate vertical development (see pp. 83; 93).

*Variability*

The preponderating effect of heavy rainstorms and the relatively small areas affected by strong convectional-cells tend to cause tropical rainfall to vary appreciably in time and amount.

* Compare London 4 hr/mean day; Birmingham 3·6 hr.

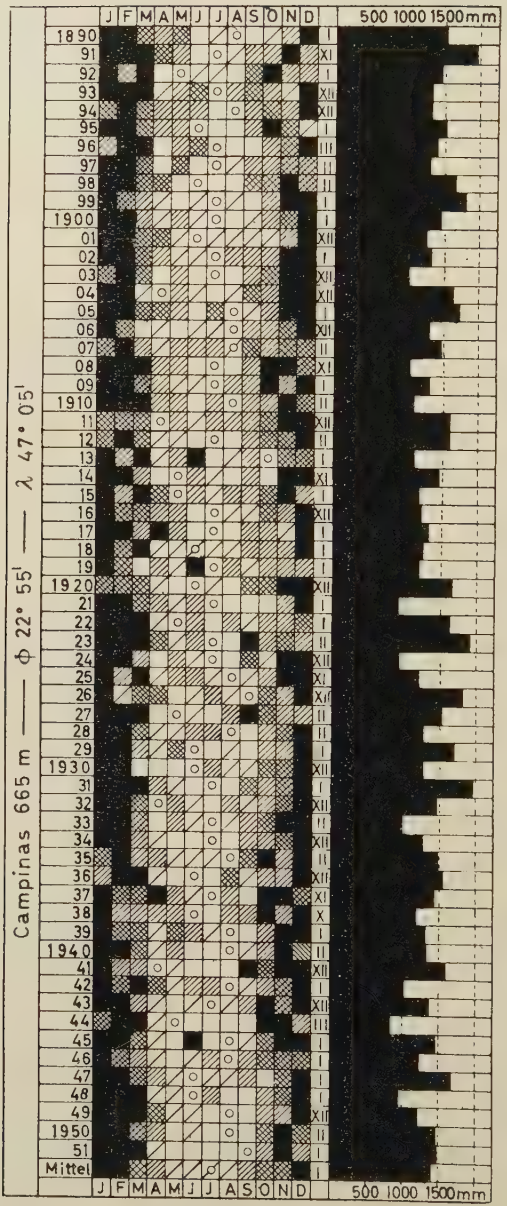



*Figure 9. Pluviogram for Campinas, Brazil, 1890–1951. In columns of monthly rainfall black denotes wet month (12·5% or more of annual total); cross-hatching, 8·3–12·4%; dense hatching, 4–8·2%; thin hatching, 2·0–3·9%; and white 0–1·9%. Small circles show driest month and Roman numerals wettest month. Solid columns are actual annual totals with mean (Mittel) at base (after Schröder)*

*Annual*—In regard to annual totals only the wetter areas with no dry season have average variations from the mean of less than 15 per cent. Elsewhere the average variability from the mean tends to increase with the length of the drought period, being up to 25 per cent in regions with moderate dry seasons and up to 40 per cent in non-desert areas where the dry-season is long, including inland parts of north-eastern Brazil.

The actual annual variations remain of practical value even where the total rainfall is large. The absolute maximum and minimum and the range of rainfall are often mapped (*Figure 7*). The mean maxima and minima are perhaps best represented by the upper and lower quartile values of annual dispersion diagrams. In drier areas where strong variations threaten crops, the probabilities of receiving certain selected amounts, for example, 20 in. are often calculated and mapped (*Figure 8*)*.

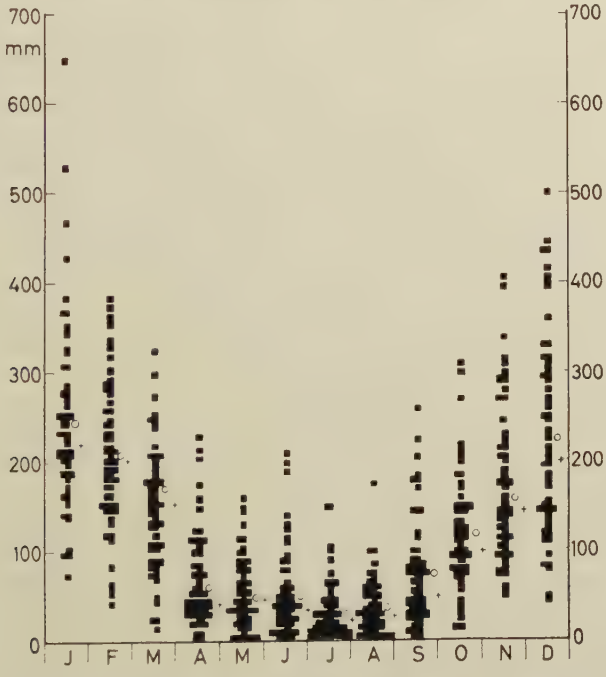



*Figure 10. Dispersion diagram of monthly rainfall at Campinas, 1890–1951. Small circle shows mean rainfall and cross approximate median rainfall. Notice how months of very heavy rainfall tend to exaggerate the mean (after Schröder)*

The possibilities of marked secular changes in rainfall, annual and seasonal, cannot be ignored and recently it has been suggested that tropical rainfall, other than in monsoon south-eastern Asia, decreased considerably at the close of the nineteenth century. It seems that ' our classical model of easterly trade winds converging to the equator is by no means sacrosanct '[10], and that a small change of conditions could alter it greatly (see E. B. KRAUS[11,12]).

* The reliability of the average moisture index on the Thornthwaite system has been computed for East Africa[9].

*Monthly variability*—Owing to the rather localized nature of many tropical downpours, monthly rainfalls in the tropics show large variations, and droughts occur occasionally even in parts of the evergreen forest. Away from the wetter areas, droughts can occur occasionally in almost any month except perhaps in the heart of the rainy season*. This problem, however, lies outside the scope of a brief summary and suffice it to draw attention to the value of the dispersion diagram for stressing rainfall amounts and of the pluviogram for emphasizing temporal shifts in amount. Dr Rudolf Schröder's recent studies on tropical South America, from which *Figures 9* and *10* are taken, strikingly demonstrate this although the territory probably has a more reliable rainfall than have tropical Africa and Asia.

Short extracts from a graphic account of the climate of Nigeria will serve our general purpose well. Here during the rainy season heavy downpours ' alternate with dry days in a manner at once typical of inter-tropical front weather and fraught with all the dangers from soil erosion and leaching so characteristic of the tropics '. Preceding and following it are the ' tornado ' seasons when ' the concentration of the rain into short sharp downpours may leave harmful blanks in both time and space. As regards time, this may have the serious consequence of allowing the corn seed, which one storm has allowed to germinate to die before another saves the situation . . . As regards space, one village having had three nicely-spaced storms may have corn ready for singling out, while a neighbouring village may not yet have been able to plant its seed '[13].

## CAUSES OF PRECIPITATION

Although ' there is not even agreement on the common forms of tropical clouds or on the meteorological conditions accompanying them '†, the causes of rainfall in the tropics are presumably much the same as those in other latitudes. Their relative effect and relative frequency are, however, very different. The one basal cause—adiabatic cooling of air-masses through enforced ascent to well beyond the dew-point—may be grouped for convenience into:

(*i*) convective;
(*ii*) orographic;
(*iii*) cyclonic or frontal.

In practice it is frequently impossible to distinguish individual factors as the first two usually operate together and the influence of the third, even when not definitely detected, is often suspected.

### *Convection*

Association with the convective overturnings of moist unstable cells is the prime characteristic of tropical precipitation. Elephantine lumps of cumulus are harbingers of storms and of the wet season but cumulus skyscapes vary greatly in character. In the thick equatorial air-masses vast cumulonimbi may tower to 55,000 ft or more while the massive but lower cumulus congestus is common. Where a Trade, or other, inversion

* Diurnal variation of rainfall is discussed by Watts (ref. 4 pp. 67–71) and Riehl (ref. 1 pp. 109–111).

† C. E. Palmer, in *Compendium of Meteorology*[14], p. 860 *cf.* p. 878: ' Above all we need an extensive investigation of the necessary and sufficient conditions for the formation of rain in the tropics '.

is present cumulus clouds are as a rule relatively shallow and small, ranging from Trade cumulus, where the inversion layer is highest and weakest, through chimney clouds to cumulus humilis where it is low and strong.

Precipitation will necessarily depend on the nature of the air-mass and the rapidity and prolongation of its ascent. Convective rainfall depends on differential convection and operates mainly by means of small cells, myriads of which spring into being daily within the tropics and many of which, in the equatorial trough, drive high into the top of the troposphere*.

The general nature of thunderstorms has long been realized but only in the last 30 years have intimate details been revealed. The typical thunderstorm consists of a number of ' cells ' which, as a rule, have individual horizontal dimensions of from about ½ mile up to 6 miles. In an aerosol already liable to be rather unstable because of regional conditions, many local factors are capable of encouraging relatively rapid ascent and of triggering-off the overturning of a cell. Once started, the convective cell develops at a tremendous rate and usually within 20 to 60 minutes has completed its cycle.

During this cycle the downdraught of rain-cooled air from the cell usually triggers off the overturning of other cells. Much appears to depend on the spacing of potential convective cells, and distances apart of up to 3 or even 5 miles seem peculiarly favourable to cell-propagation. Although in a practically uniform air-mass the individual storms may occasionally actually have a random or irregular pattern it seems that usually they group themselves into lines or bands which in time move across the sky mainly by means of the propagation of new active cells. In some areas these ' progressions ' may be due to potential cells passing successively over, *or under*, a more or less stationary trigger-action; in others, there may be ' squall-lines ' in the lower atmosphere.

The nature and life-cycle of typical cells are summarized in *Figures 11* and *12*. It must suffice to draw attention to a few of their interesting climatic features.

(*i*) Prolonged ascent in thick air-masses usually leads to the formation of ice-crystals, snow and hail. These usually melt before reaching the ground but hail-storms are experienced occasionally, for example, at Singapore, even at sea-level near the Equator. Where the ground-surface is high, as on the African plateau, hail-stones of exceptional size may crash to earth.

(*ii*) Although the bulk of convective precipitation in the tropics is associated with the formation of ice-crystals above freezing-levels, rain does fall quite frequently from shallow clouds with temperatures above freezing-point. In Hawaii, and no doubt in many trade-wind regions where or when the inversion-layer is highest, precipitation from ' warm ' clouds less than 7000 ft thick ' contributes substantially to the total rainfall of some areas '. Here the raindrops are often quite large and the intensity frequently reaches 0·4 in./hr.

(*iii*) The formation of ice-crystals and the splitting of large rain-drops in convective cells encourage electrical discharges. The wetter tropics, and

* And so presumably feed aloft the high-level air-flow which sinks eventually in the sub-tropical anticyclones.

more particularly the equatorial trough, form the world's chief lightning zone. On an average Penang has thunder on 204 days and Bogor in Java on 322 days a year—a world record. The effect of lightning on radio-

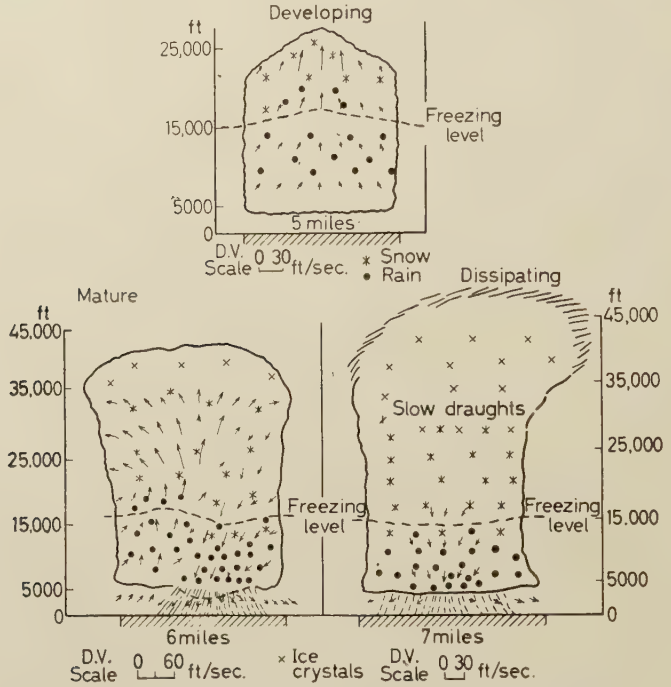



*Figure 11. Idealized cross-section of a thunderstorm cell. Surface rain is shown by dashes; D.V. denotes draught-vector scale, length of arrows being roughly proportionate to air-speed (after Byers)*

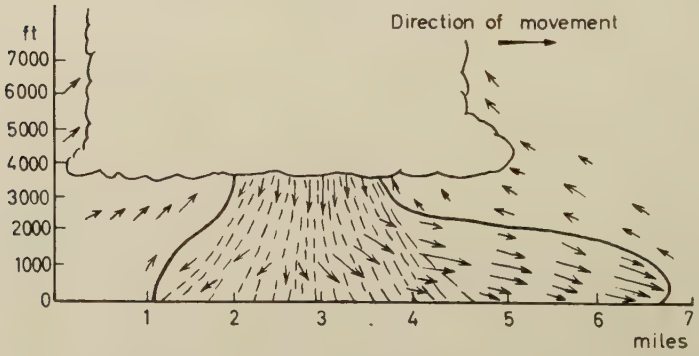



*Figure 12. Schematic section showing the spreading of the downdraught from a thunderstorm cell (after Byers)*

communications is bad but little seems known of the possible destruction in forests, especially where the trees grow in permanently wet soils.

(*iv*) The winds associated with convective cells are of great importance. At first the surface wind blows gently towards the cell or ' progression ' but

when a cell reaches its early mature stage and rain begins to fall from the cloud-base, the surface-wind changes in direction and soon begins to blow outward from the cell. Usually there follows a sharp increase in wind-speed, occasionally to destructive force and this major gust is succeeded by a period of strong gusty winds. The onset of the first outward blast varies somewhat. It is caused by the rain; the rain-chilled air subsides together with air entrained in and driven before the downward rush of a vast mass of water (*Figure 12*). As the cell dissipates, the outward wind weakens and after a few hours the surface movement tends to return to its original state. These cold-air blasts, or squalls or squall-lines locally, frequently trigger-off near-by potential convective cells: they are the ' rushing mighty wind in the tree-tops ' of early travellers, and altogether form a major weather feature, even in haboob-prone areas.

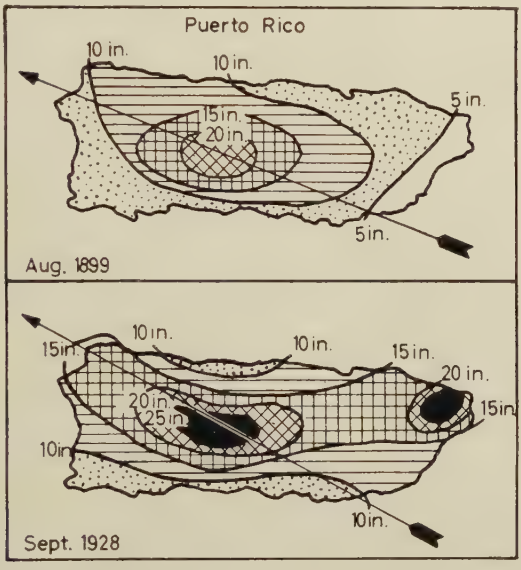



*Figure 13. Rainfall during the passage of hurricanes: arrow shows path of hurricane centre (after Tannehill)*

## OROGRAPHIC RAINFALL

The diurnal thermal pulsation of mountainous areas greatly encourages local convectional overturnings. High islands in the tropics usually form ' orographic cells ' in which clouds form over the higher parts of the island and also, to a lesser degree, some distance offshore (*Figure 5*).

As already discussed, the forced ascent of prevailing winds over a relief barrier is a potent factor in the precipitation of many tropical areas. This orographic ascent accentuates other causes of rainfall when they are present. The actual physical or mechanical details of the air-streams are summarized by R. S. Scorer and others but they have not been applied widely to tropical climatology. However, a few general, simple points may be made.

Orographic air-stream ascent is less abrupt than that in convective cells. It is, for example, spread over a much greater horizontal distance, especially

as the air-mass usually begins to rise before the actual obstruction is reached. Thus lowlands at some distance to windward have relatively heavy rainfalls.

The orographic effect on the air-stream depends on the air-stream itself and on the relief. Small islands may be circumvented or surmounted by the wind and, in the latter event, may experience lee-wave eddies and extraordinary droughts to leeward. The lee-side of mountain ridges, especially of those lying athwart the prevailing wind, may commonly experience downdraughts and/or *föhn*-effects which accentuate rain-shadows locally.

There is also the possibility that high ridges may cause turbulence in the lower atmosphere and squall-rains at some distance to leeward. Thus the early morning ' sumatras ' of the warmer months in south-west Malaya ' almost invariably occur in predominantly westerly winds (up to at least 10,000 ft) of moderate speeds, and are likely therefore to be a delayed result of forced ascent over the mountain ranges of Sumatra '[15]. If this is so, the ' sumatra ' squalls join the large family of tropical ' organized lines of cumulus or cumulo-nimbus, accompanied by wind-shifts which simulate cold fronts of high latitudes but are due to diurnal and orographic causes ' (ref. 14 p. 872).

### CYCLONIC OR FRONTAL FACTORS

The dynamic or synoptic meteorology of the tropics is a battlefield at present in a state of great activity. To take two examples: the former ideas of airflow over south-east Asia have been drastically altered by B. W. Thompson; the problem of the existence of true frontal discontinuities in the equatorial region has called forth the following contentions:—' There is still no reason for discarding the old term tropical front (T.F.) and for calling the mechanism the intertropical convergence zone (I.T.C.Z.). The T.F. has, in fact, all the properties of a front '[16]. ' It is best to abandon the use of the term " intertropical front " between latitudes 10° N and 10° S and to replace it by the expression " equatorial air-stream boundaries ". Outside these latitudes, however, the term is permissible ' (ref. 4 p. 101).

Yet in spite of these uncertainties there is general agreement that dynamic or cyclonic factors do operate widely in the Tropics. There are vast-scale air-masses which wax and wane and move long distances regionally. The advancing or oscillating edges of the moister air-masses usually give much rain and often, outside the equatorial belt, seem to be associated with local ' lows ', as on the coast of West Africa and Madras. These ' lows ' seem mainly non-frontal or virtually so. There also seem to be occasions when air-conditions aloft have much influence on the amount of rainfall, especially during the presence of ' perturbations or waves in the easterlies '.

The nature of the contact of the air-masses is quite beyond our discussion but it is well known how the migrations of the trade-wind zones are accompanied by heavy rainfall at their onset and during the surges that follow. The rainfall usually decreases, as the system becomes fully established. Yet in invasions by the ' equatorial trough ' the rains come mainly when the air-mass has settled in over a region. In other words, the ' front ' or zone of contact varies greatly and much depends on the depth of the moist air-mass and on the strength of inversions aloft.

The problem of dynamic or frontal factors inevitably leads to that of tropical cyclones. The much smaller tornado of West Africa seems a local phenomenon connected with convective cells especially at the time when the main equatorial air-mass is advancing or retreating haltingly over the land. Tropical cyclones proper form the most powerful wind-systems of the earth's surface. It appears that they arise within weak pre-existing ' lows ' when ' easterly waves ' cause instability aloft, and develop within these ' lows ' into revolving hurricanes. Thus dynamic divergence aloft acts as a trigger-action or encouragement.

Usually the heaviest rainfall occurs on the average some 15 miles from the centre of the tropical cyclone and is as intense in the rear[17] as in the front of the ' eye '. Rainfall is rarely small; falls of over 5 in. in 24 hr are common, and of over 20 in. by no means rare on steep coasts. The heaviest rainfalls in the west Pacific, West Indies and north-east Australia are associated with typhoons or hurricanes. Of the 48 which are recorded within the tropics during an average year, over half occur off south-eastern Asia where the west Pacific and the China Seas are peculiarly liable to be struck by what Sutcliffe (ref. 10 p. 387) calls a ' water-driven turbulence element—a sort of hybrid between the convective and cyclonic system '.

ACKNOWLEDGEMENTS

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# *The Institute of Rural Life at Home and Overseas*

P. Eastman

*Secretary of the Institute of Rural Life*

Twelve years ago seventy-five men and women of different races, countries and professions met together in conference. They were anxious not only to understand the problems of country life in their own lands; but also to discuss how best to serve the needs of masses of the world's people living for the most part in rural conditions. As a result of this and subsequent conferences on these basic questions, the Institute of Rural Life at Home and Overseas was established in 1949.

It now enjoys the confidence of the following bodies, most of which are represented on the Executive Committee:

Associated Countrywomen of the World;
Association of Agriculture;
British Council;
Church Missionary Society;
Colonial Office;
Conference of British Missionary Societies;
Friends International Centre;
London Missionary Society;
Methodist Missionary Society;
National Council of Social Service;
National Farmers' Union;
National Union of Agricultural Workers;
Society for the Propagation of the Gospel;
Young Men's Christian Association;
Young Women's Christian Association.

The Institute is fortunate to have as its President, The Rt Hon. Lord Tweedsmuir, son of the well-known author John Buchan, and himself the author of *Always a Countryman*[1].

In addition the Institute enjoys the counsel of a number of Vice-Presidents representative of both Church and State, and national and international organizations among whom are: Alderman E. G. Gooch, President, National Union of Agricultural Workers; Sir Kenneth Grubb, President, Church Missionary Society; The Rev. R. K. Orchard, Secretary, International Missionary Council; Sir Hilton Poynton, Deputy Under-Secretary of State for the Colonies; The Rt Rev. B. C. Roberts, Secretary of The Society for the Propagation of the Gospel in Foreign Parts; Professor H. G. Sanders, Chief Scientific Adviser (Agriculture), Ministry of Agriculture, Fisheries and Food; Sir John Shaw, Formerly Governor of Trinidad and Tobago; Sir Paul Sinker, Director-General of the British Council.

Under the Rules of the Institute there is provision for two classes of members:

(*a*) persons who have been admitted to membership by the Executive Committee;

(*b*) persons nominated by the affiliated societies approved from time to time by the Executive Committee.

The Institute is at present in touch with some two hundred societies and associations, whose interests lie with one or more of the many aspects of rural life, or which in some way share the objects of the Institute*.

### AIMS AND OBJECTS

The aim of the Institute is ' to draw together on a Christian basis and to further the education of all people, of any race or occupation, in the understanding of rural life '. The objects and methods by which this is done may more generally be described from Rule 3, which states that the Institute exists ' for the purpose of promoting the education of those people whose work is concerned with the advancement of religious knowledge, with education, formal and informal, with administration and with the furtherance of health and the relief of poverty, distress and sickness among people living in rural areas at home and overseas, by means of:

(*i*) the provision of a clearing house of information, published and unpublished;

(*ii*) the publication of reports, periodicals, books or pamphlets;

(*iii*) the organization of conferences, exhibitions, meetings, lectures, courses, and visits calculated to further the objects of the Institute or any of them.

### CLEARING HOUSE

The Institute is building up a specialized library. This is at present small in comparison with some centres of learning. But it includes many volumes, pamphlets and documents giving information of inestimable value to the urban dweller who is going to live in rural areas overseas. Enquiries received from members and others seeking information are answered by correspondence or personal introductions to appropriate experts. In this way members of the Institute help each other in the understanding of rural life. Information about new machinery and equipment, scientific methods in agriculture, and economic and social development through mutual aid is welcomed and shared.

### PUBLICATIONS

The list of publications available has been compiled on a selective basis. There are at present some 26 booklets, pamphlets and reports on sale. Of especial interest are the articles appearing in *Rural Life*, the quarterly publication of the Institute.

Early in the life of the Institute a modest bi-monthly bulletin was so widely welcomed that a *Rural Life Journal* was issued in August 1954. In the first issue the President wrote ' undoubtedly, there are many people, and not a

*Applications for membership (annual subscription £1) may be made to, and interested callers will be welcomed at, the Institute's headquarters at 59 Bryanston Street, London, W.1. Appointments may be made by telephone to AMBassador 0091.

few organizations, who are vitally interested in the same objects as we are; but who have not yet heard of this Institute or its work '. We believe that our community of interest and opportunities of service will extend the membership of the Institute. It continues to grow steadily, and for a modest annual subscription of one pound sterling or its equivalent members receive the journal in February, May, August and November each year.

### OVERSEAS CORRESPONDENTS

One of the distinctive features of the journal is the variety of contributions from those officially designated Overseas Correspondents of the Institute. There are at present some ninety who contribute information of a most practical kind drawn from a wide variety of experience. Some areas of the world are not yet as well covered as others. Enquiries from readers willing to provide information, news and views in notes or articles will, therefore, be welcomed. The names and addresses of Overseas Correspondents in any area will be provided on request to registered members of the Institute. In the first and subsequent numbers of Volume II of the journal to be issued under the title *Rural Life* there will be a special section devoted entirely to this service of Overseas Correspondents.

The journal contains reports of Conferences and Courses of importance, including those of the Food and Agriculture Organisation, and some of the most significant addresses delivered at those convened by the Institute. Thus the last six issues have contained reports on: *The International Conference on the Church and Rural Life* held at the Ecumenical Institute near Geneva in August/September, 1956; *Rural Life in British Guiana* by Sir ALFRED SAVAGE, formerly Governor of Barbados and of British Guiana; a report on a special Seminar arranged in Oxfordshire for delegates from the National Council of Churches of Christ in the United States of America, during August, 1956; *Rural Change and the Need to Re-adjust* by Lord TWEEDSMUIR; *The School and the Rural Community* by Mr P. C. C. EVANS, of the Institute of Education, London University; A statement on American Abundance and World Need. One issue contained notes and news from Canada, Cameroons, Costa Rica, Netherlands, Zanzibar, Zululand and the United Kingdom. There have also been reviews of some six of the most important books on rural questions recently published.

### CONFERENCES AND COURSES

Conferences of three or four days duration have been held in January, April and July, while a Course of Rural Studies in the first fortnight of September has been held for the past two years and will be held in 1957 at the Essex Institute of Agriculture, Writtle, near Chelmsford. The next Conference will be 9 to 12 July, 1957, at Wye College of Agriculture, Ashford, Kent. The Annual Conferences in January during the last three years have been: 1954 Rural Life at Home and Overseas; 1955 Five Pillars of Rural Society—Church, Health, Housing, Land, School; 1956 Community Development in Rural Areas at Home and Overseas. These titles alone show the diversity of subjects discussed. At the last Conference there was also an exhibition showing the community development work of organizations associated with the Institute.

The Course of Rural Studies in September, 1956, was attended by some forty-five persons—six colonial students, nine missionary candidates, 19 civil servants, educational and medical officers and district administrators serving in various Overseas Territories of the Commonwealth; and others from the United Kingdom.

It was addressed among others by R. S. MARSHALL, Animal Health Adviser to the Secretary of State for the Colonies; L. LORD, Assistant Agricultural Adviser to the Secretary of State for the Colonies; H. HOLLINRAKE, Land Commissioner, Ministry of Agriculture, Fisheries and Food; Dr H. GREENE, Adviser on Tropical Soils to the Secretary of State for the Colonies; P. E. W. WILLIAMS, formerly Director of Education, Zanzibar.

The course included not only lectures, films and discussions; but also practical demonstrations of outdoor cooking appliances; livestock judging; milking and handling of milk; vegetable and fruit growing; the use of hand tools; tractor driving; bee-keeping, and so on.

The Overseas Agricultural Talks Producer of the British Broadcasting Corporation described this course in the General Overseas Service on 10 September, 1956. He enlarged upon a discussion at one lecture, and later made recordings of some of the main participants.

'A visitor from Nigeria,' he reported, 'had said that Rural Education Centres could do a lot and this led on to a discussion of the controversial subject of school farms and school gardens. A Gold Coast teaching assistant said that in his view a school farm was something outside the school. It was not the job of schools to teach the children to farm. On the other hand a school garden helped to give children an appreciation of the soil and was well worth having. Other speakers supported the idea of a school farm, and it may be that, as one speaker said, " while nobody wants a badly run school farm, there is a lot to be said in favour of one that's properly organized " '.

'An agricultural missionary from the Southern Sudan said that in his view the most important thing about teaching agriculture was that the instructor should be a farmer himself, and should be willing and able to work with his hands. He cited the case of a man called HERRINGTON, who became almost a legendary figure in Nigeria, and whose success with the farming people there was, he said, based on the fact that he knew how to climb a palm tree and tap palm wine ! '

It is a commonplace to say that two-thirds of the world's population live in rural areas, and that in the atomic age we must cultivate the science of human relationships if we are to survive. The Institute, recognizing these facts, seeks to contribute to the vital task of education in the understanding of rural life that men and women everywhere may be free from ignorance, want and disease, and that all shall learn to live together with mutual understanding and goodwill.

(*Received January 1957*)

REFERENCE

[1] BUCHAN, J. (1953). *Always a Countryman.* London: Hale

# *Agricultural Co-operation in Uganda*

A. J. Kerr

*Commissioner for Co-operative Development, Uganda Protectorate*

One of the most remarkable developments that have taken place during the past half-century of British administration of the Uganda Protectorate is that of agricultural co-operation. It is certainly remarkable to those who have been closely concerned with its development during the past ten years and who were aware of the ignorance and apathy of the peasant masses which existed previously. Few Africans had any idea even of how to keep a cash-book, or to operate a post office savings account, to conduct a meeting or record the minutes, let alone of how to manage a business. It is therefore an incredible experience now to attend the annual general meeting of a co-operative union with a membership of anything from 10,000 to 50,000, to observe the proceedings conducted in a manner that would not shame the Legislative Council and a complicated balance sheet of an organization with a turnover exceeding £1,000,000 per annum considered intelligently. On the other hand, it would give a false impression to pretend that there is other than considerable scope for improvement. But some advance has been made from the days when one of the first Co-operative Officers, on inspecting a society, called for the accounts and records. One file was produced headed, ' Correspondence to and from Nowhere '.

## DEFINITION

To many people a co-operative society conjures up a picture of a co-operative shop in an industrial area, to others it may mean the co-operative credit society which is so well known in eastern countries. In Uganda, however, it is the producer co-operatives which form the main branch of the movement, particularly as regards the production, marketing and processing of crops. Co-operation is really a form of business in which people join together to help themselves, and agricultural co-operation may be defined as an organization in which people associate voluntarily, on a basis of equality, to promote their economic interests, primarily agricultural.

## DESCRIPTION

Before proceeding further it is perhaps desirable to give a short description of Uganda. It is situated astride the equator on the plateau of east-central Africa at a general elevation of 4000 ft above sea level. With a total area of some 94,000 square miles, of which nearly 14,000 square miles are open water, it has a land area less than that of England and Scotland combined and a population of about 5,000,000, comprising roughly 1,000,000 families, mainly peasant agriculturists cultivating small-holdings of a few acres. They produce some 350,000 bales (400 lb.) of cotton and 60,000 tons of coffee, Robusta and Arabica, annually. Other

cash crops include tobacco, maize and groundnuts, besides which there is a flourishing livestock industry. The total income of the African farmers from these sources is in the region of £45,000,000 per annum.

Before the development of the co-operative movement, trade in the Protectorate was largely concentrated in the hands of aliens, especially Asians, both as regards the marketing, processing and export of produce and the importation and distribution of consumer goods. After the war, however, an increasing desire by the African to participate in trade became apparent, particularly in the cotton ginning industry in which it was difficult for the individual African to obtain a footing.

## HISTORICAL

Although co-operative development had engaged the attention of Government as far back as 1934, it was not until 1946 that the movement received official and formal recognition by the enactment of co-operative legislation. Various indigenous forms of co-operation had existed in the Protectorate from time immemorial and, as early as 1913, some African farmers in Singo County of Buganda marketed their crops co-operatively, but an event with more far-reaching results took place in 1920 when five Baganda farmers came together in Kampala under the style of ' The Baganda Growers' Association '. Their object was to form a body through which the views of the African grower could be voiced to Government. This organization made some attempt to market cotton co-operatively in 1931, though with disastrous results. In 1933, with the assistance of a European accountant and a European ginnery manager, it was reconstituted under the name of ' The Uganda Growers' Co-operative Society '. The members of this society were drawn from various counties in Buganda and formed the nuclei of what were later to become separate primary societies which, in 1935, became loosely associated under the name of ' The Uganda Growers' Co-operative Union '.

## LEGISLATION

Meantime, in 1932, the author, as Agricultural Officer in Bugisu District, organized a co-operative pruning club among coffee growers on Mount Elgon and put forward a recommendation that co-operative legislation should be enacted.

In 1934, the Uganda Growers' Co-operative Society wrote to the Attorney General, Entebbe, requesting the enactment of co-operative legislation. A Co-operative Societies Bill was drafted in 1935, revised in 1936 and given its first reading in Legislative Council in 1937, but it encountered strong opposition and was withdrawn pending an investigation of the subject by an Administrative Officer whose report on the introduction, regulation and development of the co-operative movement was submitted in November, 1938. When the report was considered in April, 1939, it was decided that further action to introduce co-operative legislation should be postponed until matters arising from the Report of the Uganda Cotton Commission, 1938, had been settled. The war intervened which led to a further postponement until 1944, when W. K. H. Campbell, previously Registrar of Co-operative Societies in Ceylon and League of Nations Adviser on

co-operation, was invited to undertake an investigation in Uganda. He submitted a ' Preliminary Report on Co-operation in Uganda ' in which he urged immediate action to control and assist the numerous quasi-co-operative societies already in existence by the enactment of legislation to incorporate the co-operative principles which have emerged after a hundred years of trial and error and to provide for the establishment of a co-operative department to guide and supervise the movement.

In 1945 a Bill was introduced into Legislative Council which, after various amendments had been made in the light of a model Co-operative Societies' Ordinance[1] issued with a dispatch from the Colonial Office, was finally enacted as the Co-operative Societies' Ordinance, 1946, and brought into operation on the first of September, 1946. Rules under the Ordinance were finally promulgated in March, 1947.

In view of the indications that agricultural co-operation would be an important aspect of the co-operative movement in Uganda the writer was appointed as Assistant Director of Agriculture and Registrar of Co-operative Societies with effect from 1 January, 1946, and was sent on a study tour in Tanganyika Territory, Ceylon and India.

## PRODUCE CONTROLS

During the 1939–45 war various produce controls had been established including those for cotton, coffee and maize. The cotton and coffee controls were later superseded by the Lint Marketing Board and the Coffee Industry Board. Cotton marketing is controlled under legislation which provides for registered associations of ginners, known as ginning pools, to operate in the various raw cotton zones. Separate legislation provides for the purchase from ginners at fixed prices of all lint cotton and cotton seed to be the responsibility of the Lint Marketing Board, there being a cotton price assistance fund to act as a buffer against undue variations in world prices. Similarly, in the case of coffee (other than Bugisu which is controlled under separate legislation) the marketing and export is controlled by the Coffee Industry Board. With the exception of that processed by ' estates ', coffee is required to be sold through the Coffee Industry Board, there being again a coffee industry fund to buffer price variations.

### *Maize*

An organization known as the Tripartite Produce Agency had been established during the war to act as the agent of Government in respect of certain crops, including maize. In some districts cotton ginning pools were appointed as sub-agents for maize, they being the only organization with the requisite buying, storage and transport facilities to deal with the crop. In an endeavour to assist the co-operatives Government had, however, arranged for the Uganda Growers' Co-operative Union also to act as a sub-agent on parallel terms with the ginning pools. This arrangement was to the economic advantage of members of the co-operative societies as they not only obtained transport economies and enhanced prices for bulk deliveries, but the individual members, who were mainly illiterate, also obtained fair weights and payments. In 1946, over 2000 tons of maize was marketed through the Uganda Growers' Co-operative Union.

*Cotton*

The re-organization of the cotton ginning industry had been under review for some years but by 1946 it became clear that co-operative societies could play an important part. It was felt that in the first case primary societies of producers could be formed to sell their cotton on a commission basis to the local ginners and that subsequently a union of these societies would be financially strong enough and have sufficient cotton to warrant the operation of a cotton ginnery. For example, take a small primary society with only 50 members each producing, say, 720 lb. of seed cotton. The total of 36,000 lb. seed cotton is equivalent to 30 bales of lint. It is no great hardship for the member whose seed cotton is worth about shs. 400*s* to buy one shs. 20*s* share in his society per annum. If one hundred such societies unite to form a union, it not only commands cotton equivalent to 3000 bales but funds amounting to £5000 per annum and a prospect of entering the ginning industry are brought within its range. This was the proposition put forward by the author in 1946.

Development took place along these lines, particularly in Mengo District. By the end of 1946, about 75 organizations of a co-operative nature were known to be in existence, some of which had come into being after the enactment of the legislation. Of these, about 50 were engaged in produce marketing, the most important being a group of 23 affiliated to the Uganda Growers' Co-operative Union, mentioned above. The first primary society was registered in July, 1947 and by the 1949/50 cotton season the Uganda Growers' Co-operative Union, Limited, which was registered in 1948, was able to lease a ginnery at Ngogwe which had been purchased by the Buganda Government from funds allocated to it by the Protectorate Government from the cotton fund which had been built up during wartime. The ginnery operated successfully and in the following season the union was able to rent a second ginnery near Kampala.

The Uganda Cotton Industry Commission, 1948, though somewhat limited in its terms of reference, recommended that all possible encouragement, guidance and assistance should be given by Government to co-operative marketing societies and that provision should be made for the admission of Africans as ginnery owners. Consideration of this report culminated in the publication of a white paper in September, 1951, containing the Government proposals for the re-organization of the Uganda cotton ginning industry. Among other things, they provided for Government, in the first five-year period ending in April, 1957, to acquire ginneries with a capacity of up to 50,000 bales, i.e. 20 ginneries, for transfer to co-operatives and in the second five-year period for co-operatives to obtain a further capacity of 50,000 bales in respect of increased production by the erection of new ginneries or by increasing the shares in the ginning pool of existing co-operative ginneries. To implement this scheme Government proposed to take powers for the compulsory acquisition of ginneries required for transfer to co-operatives on the understanding that they would produce one-third of the capital from co-operative resources and that the balance would be loaned by Government for repayment over a 30 year period at $5\frac{3}{4}$ per cent per annum to cover interest and amortization. These proposals were given legislative effect in April, 1952. As certain unions were unable to raise

the necessary funds in time, provision was made by amending legislation for ginneries to be leased.

When a ginnery is transferred to a co-operative, the latter is required to pay the full value of the capital assets as assessed by valuation at the time of acquisition, whilst Government bears the remaining costs. The average transfer cost of a ginnery to a co-operative has been about £40,000. By the end of the first five-year period 11 ginneries were in the hands of six co-operative unions. Of these, eight had been compulsorily acquired, one purchased by negotiation, one built by Government and one leased from the Buganda Government. Already some 20,000 bales of cotton are ginned annually by co-operatives. In addition, almost as much again is sold direct to commercial ginneries to avoid the penalties for being over quota.

For the operation of their ginneries the unions employ African staff as far as possible but they usually engage non-African managers and engineers. The unions concerned have all operated their ginneries profitably, though they are not expected to operate as profitably as commercial ginneries because of the necessity of observing fair weights and payments to members.

### CROP FINANCE

For seasonal crop finance, the unions are able to obtain an overdraft from the commercial banks on the second mortgage of their ginnery and by hypothecation of cotton stocks. Hitherto, because they have been suffering from a shortage of capital, the surplus (profit) has been credited to the members, i.e. the affiliated primary societies, in the form of shares in the union rather than attempting to pay a cash bonus to individual producers. The latter obtain the fixed price for their cotton, as they would if they sold to ordinary commercial ginneries, but as owners of the primary society their stake in it is increased.

### PRIMARY SOCIETIES

The primary societies have as their main objects the marketing and processing of produce; the improved production of crops; the supply of agricultural and building requirements; and the provision of facilities for thrift and credit. Each society has its own registered byelaws and is constituted in accordance with co-operative principles to provide a service to members rather than with a motive of profit-making from non-members. Membership is, of course, entirely voluntary. There is democratic control through an elected committee and each member has one vote independent of his shareholding. Share capital is obviously necessary for the societies' operation, but, in practice, members usually make equal contributions of share captial and often no interest is paid. Instead, the surplus, having been derived from the business done by members with the society, is returned to them (after appropriate deductions to reserve or other funds have been made) in proportion to the business done with the society, i.e. the value of produce sold and goods purchased. The society normally uses its initial share capital to build a small store, buy a scale and a set of account books. Members deliver their produce, obtain a produce receipt and the society arranges its sale. Sometimes the members are paid cash on delivery,

sometimes they wait until the society has received payment. Anyhow, they can be sure of obtaining fair weights and payments and the small producer, who might otherwise have to deliver his produce by head-load or bicycle to a market some miles distant, is saved much time, labour and inconvenience. The society arranges the onward sale of produce, either to the Union, or sometimes to another buyer in which case it obtains a small commission from the buyer for undertaking the service of primary collection.

As regards the improved production of crops, these societies are useful channels for the dissemination of propaganda, e.g. as regards time of sowing, spacing, etc. Assistance has recently been given with the distribution of an illustrated pamphlet on cotton prepared by the Lint Marketing Board. In some primary societies, the spraying of members' cotton against *Lygus* damage has been undertaken in collaboration with the Department of Agriculture, with very satisfactory results, whilst one co-operative union undertakes the dressing of cotton seed against blackarm disease on behalf of Government.

*Coffee*

Following upon the formulation of the policy for re-organization of the cotton ginning industry, Government proposals for the re-organization of the coffee industry (excluding Bugisu) were published in 1952. Up to that time, as was the case with cotton, coffee processing had been a monopoly and it was virtually impossible for Africans to participate. Legislative effect was given to the proposals in 1953, when provision was made for the establishment of a Coffee Industry Board and for additional coffee curing works to be licensed. The first four new curing works in Mengo District and the first two in Masaka District were reserved for Africans. A licence for one of the latter was issued to the Masaka District Co-operative Union whose £20,000 factory completed its first year of operation in 1955. The 38 member societies delivered 2605 tons of sundried cherry and, after allocation to statutory reserve, the balance disposable was £23,254. The economic advantage to the members of marketing through their co-operative organization is clear from the fact that a bonus of 7 cts/lb. of sundried cherry was paid to members in respect of coffee originally paid for at the controlled prices of 1 shs. 25 cts and (from May onwards) 75 cts/lb. delivered at curing works. Another £25,000 has since been spent on an extension to the factory.

One of the four licences for Mengo District was also issued to a co-operative union which erected a £55,000 coffee factory, of modern design, which was opened in 1956. This factory has a capacity of some 4000 tons of clean coffee but is designed with a view to extension.

BUGISU

The Bugisu (Arabica) coffee industry is worthy of special mention. Whereas Robusta coffee in Uganda is mainly prepared in the form of sundried cherry prior to hulling and grading, the Arabica crop in Bugisu has always been prepared by the wet process—pulping, fermenting, washing and drying—in the form of ' parchment ' coffee, but the preparation of a

multitude of small parcels of poor quality parchment coffee by individual growers, combined with the low prices prevailing in the early 1930's, led to the formation of the Bugisu Coffee Scheme—a superimposed Government organization for the processing and marketing of coffee. The Bugisu Coffee Scheme established a series of pulperies for the purchase of cherry from the growers; also stores for the purchase of native prepared parchment. At strategic points drying centres and a coffee factory were built. One of the results was a material improvement in the quality of the native prepared parchment due to the employment of Bagisu in the pulperies. From the beginning it was the intention to convert the organization to a co-operative basis. After the enactment of co-operative legislation in 1946 the co-operative possibilities were investigated. Proposals were put forward for the formation of primary societies to collect native-prepared parchment for sale to the Board, and for the ultimate formation of a Union. These proposals were accepted by the Board and were welcomed by the growers. The first society registered there had as a nucleus the members of the coffee pruning society previously mentioned and further primary societies were registered which gradually took over the Bugisu Coffee Scheme facilities in their area until the stage was reached when five local unions, one of which was a union of cotton marketing societies, were formed. The four coffee unions eventually took over the coffee drying centres in their respective areas of operation. Finally, as co-operative experience was gained, one large central union was formed to replace the five local unions and the marketing of the whole crop was delegated by the Board to the Bugisu Co-operative Union, and the necessary staff was transferred to it including a European manager. In 1955 legislation was enacted to provide for certain capital assets previously owned by the Bugisu Coffee Scheme to be vested in the Union.

This important Union, with its 103 affiliated primary societies and 47,543 members, embraces practically the whole population of Bugisu District. Its activities are multifarious and include the marketing of the whole of the Bugisu coffee crop; the operation of the two cotton ginneries situated in the district; the operation of a savings and loan department; the sale of agricultural and building requirements to members; the provision of a maize-gristing service at one of the ginneries; the maintenance of coffee nurseries; and the provision of a coffee pruning service. The whole crop is now delivered to the primary societies which in turn deliver to the Union. The parchment coffee is then railed for curing in Nairobi and sale on the Nairobi auctions, but a £180,000 coffee mill is in process of construction locally.

During 1955, the Union paid out to its affiliated societies a sum of £2,213,400 of which about 90 per cent was in respect of coffee and 10 per cent in respect of seed cotton. Some 6600 tons of coffee and 4750 bales of cotton were sold. Quality premium bonuses averaging over shs. 13 a bale were received in respect of the output of one ginnery. At the other ginnery a maize-gristing service was provided for members living in that neighbourhood. It proved to be popular and 120 tons of maize was gristed, giving the Union a small surplus after deducting all expenses and depreciation.

Responsibility for the maintenance of coffee nurseries, taken over from

the Bugisu Coffee Scheme in 1954, was handed over to the primary societies in 1955, under the technical supervision of the Board's Coffee Officer. Seedlings were sold at six cents each. Primary societies also select pruners for training and operation under the supervision of the Coffee Officer. The total cost of £16,200 was charged by the Union against crop proceeds and worked out at $2\frac{1}{4}$ cents per tree.

The savings and loan department of the union accumulated a sum of about £50,000 in deposits from individual growers, through their primary societies. Facilities exist for granting loans to members, but little use has yet been made of this service.

As regards the sale of agricultural and building requirements, the Union operates a separate branch for the purchase of such items as coffee pulpers, pruning instruments, and galvanized corrugated iron sheets at wholesale rates for sale to members. The turnover runs into substantial figures.

### UNAFFILIATED SOCIETIES

So far an outline has only been given of the activities of primary societies affiliated to unions, which covers about 900 of the marketing and processing societies which had been registered by the end of 1956. In addition, there were 300 unaffiliated marketing societies, nine co-operative farming societies, five cattle, four fishing and three co-operative dairy societies, making a total of 1221 producers' primary societies in all, with a total membership of about 120,000 and a turnover exceeding £$4\frac{1}{2}$ million. The 300 unaffiliated primary marketing societies were situated mainly in the Northern and Western provinces. They dealt in produce such as cotton and coffee and to a lesser extent tobacco, groundnuts, maize, sesame and even fruit, their total turnover exceeding £600,000 in value. Some of these societies had previously been affiliated to an organization known as the Federation of Uganda African Farmers. It was largely to meet the objections of this group against the powers exercised by the Registrar that the Co-operative Societies' Ordinance, 1946, was amended in 1952 following the recommendations of a Commission of Enquiry. Some of the unaffiliated primary societies undertook tobacco curing co-operatively, either flue-curing or fire-curing.

*Fishing societies*

A few co-operative fishing societies have been formed with the object of enabling members to purchase fishing tackle, salt, etc. to process and market their catch co-operatively, but the fishermen are poor human material for this purpose and are frequently nomadic. However, some progress is being made.

*Cattle societies and dairy societies*

A few societies have been formed whose primary objects are the improvement of stock and the marketing of cattle and dairy produce. They undertake the purchase of requirements for members such as feeding stuffs, spraying and dipping materials and dairy utensils. In some cases milk has been marketed satisfactorily in townships and in other cases cattle have been quarantined and delivered collectively at a distant auction market.

*Farming societies*

An interesting development is that of co-operative farming societies which are of two types, the joint farming society, and the collective farming type. One of the incentives is to take advantage of mechanical cultivation. The Department of Agriculture has a special branch for the development of mechanical cultivation and undertakes the training of operators. Various mechanical units are scattered through the country and the co-operatives in the first instance took advantage of these facilities by hiring tractors for cultivation, but the stage has now been reached when three societies have formed a local union which has just purchased its own tractor and equipment. So far they cultivate an area of about 300 acres of cotton. In the joint farming societies the land is in the hands of the society but each individual member is allocated a holding for the cultivation of which he is responsible, marketing of produce being undertaken co-operatively. In the case of the collective farms the whole area is cultivated collectively and the proceeds divided amongst the members in proportion to their labour. Production per member shows a considerable increase as compared with that of other farmers in the locality. Sometimes the societies obtain a loan from the Uganda Credit and Savings Bank or from the African Loans Fund to enable them to hire mechanical equipment.

## CONCLUSION

In conclusion, it can be stated that agricultural co-operation is already a powerful factor in the economic and social progress of the people of Uganda. Since 1946, over 120,000 people who have voluntarily become members of co-operative societies have come to appreciate that, by joint action, they can do things for themselves without relying too much on a benevolent Government. Not only do they obtain economic benefit from their turnover which exceeds £4,500,000 per annum, but a new class of small capitalists has been created, in that each member has a stake in some real property, and a new class of employment has been created, both of which have a stabilizing effect on the country; moreover, the members are obtaining a practical training in democratic processes, the value of which is incalculable in an era of political transition.

(*Received February 1957*)

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# *Farm Tractors in Brazil*

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The necessity for an increase in agricultural production is perhaps the most urgent problem which the Brazilian economy, and that of many other countries too, has to solve today. The solution of this problem depends on two basic points: an increase in the total area under cultivation, and an increase in the return per unit area of cultivated land.

Furthermore, the Brazilian population has increased considerably, being now estimated at 60 million, or about three times the population of 1900. If population should continue to increase at the same rate as in recent years, then one may forecast that it will reach about 100 million people in 1980, and the country must be prepared to produce sufficient food for this population, besides the necessity for an exportable surplus.

It should also be remembered that agriculture is the main support of the Brazilian economy and still its chief source of income, in spite of the fact that large scale industrialization has taken place and that thus the increase in industrial output is also considerable. The latter, however, has created a new problem, since it produced a migration from the farming areas to the towns. The rapid growth of towns shows this clearly. Thus an increase in both agricultural and industrial productivity is very necessary for Brazil, but it must be in balance with the increase of town population unless the drift to the towns is to be halted.

It is thus urgently necessary to increase the relative productivity of the rural worker, while also raising at the same time his standard of living, and this obviously requires an expansion of mechanized agriculture in Brazil. In fact the need for mechanizing agriculture has been fully realized by the Government, and measures have already been taken to increase the number of tractors available. However, the mechanization of agriculture has not been brought about to the extent desired. Studying the number of tractors existing in Brazil—a country which only a short time ago based its rural activities exclusively on the work of the field hand, helped by animals—we can see that the increase in tractor numbers, though notable, is not sufficient (see *Table 1*). We can only repeat again and again: we need more tractors. It is sufficient to compare the existing number of 46,000 tractors —the basic and indispensable implement—and the enormous extent of available land in Brazil with the respective numbers in other countries.

With 46,000 tractors for a rural population of about 37·8 millions, we have one tractor for about every 822 people, a very low figure when compared with the situation in the U.S.A., where there is one tractor for every five such people. Making the calculation on an area basis, we find one tractor for every 485 hectares of cultivated land, and remembering that the total area of Brazil is 8,516,037 square kilometres, the needs of the country can easily be calculated.

In fact, the slowness of agricultural mechanization is a consequence of several factors, such as topographic conditions, but the most important one seems to derive from the fact that coffee growing is still the main agricultural activity. Coffee requires a large number of field hands for harvesting, which unfortunately cannot yet be done mechanically. Thus the farmer cannot think very much about mechanization in general, but must retain large numbers of field hands to guarantee harvesting of the coffee.

*Table 1*

| *Year* | *Tractors at work* | *Area of cropped land (in hectares) for 29 principal crops* | *Population of Brazil (thousands)* |
|---|---|---|---|
| 1920 | 1,706 | — | 27,404 |
| 1930 | 3,380 | 13,968,416 | 40,289 |
| 1940 | 5,206 | — | 41,114 |
| 1941 | 6,150 | — | 42,069 |
| 1942 | 6,920 | — | 43,069 |
| 1943 | 7,350 | — | 44,093 |
| 1944 | 7,998 | — | 45,141 |
| 1945 | 8,228 | 15,275,888 | 46,215 |
| 1946 | 8,790 | — | 47,313 |
| 1947 | 10,345 | — | 48,438 |
| 1948 | 11,230 | 16,219,460 | 49,590 |
| 1949 | 12,179 | — | 50,769 |
| 1950 | 17,157 | 17,775,073 | 51,976 |
| 1951 | 28,300 | — | 53,212 |
| 1952 | 35,754 | 18,792,113 | 54,477 |
| 1953 | 38,341 | — | 55,772 |
| 1954 | 40,645 | — | 57,226 |
| 1955 | 46,000 | 21,090,361 | 58,456 |

From 1930, the then small number of tractors in Brazil began to increase at a more accentuated rate, partially in response to a change in the economic structure of the country. These changes were accelerated by the 1939–45 war, and the resulting increase in industrialization in the country, caused in turn the transference of rural population, already referred to above. Thus at the same time, we have a rapid beginning in the increase of the use of tractors, a lack of man-power in agriculture and incidentally also a change to a more varied type of farming, all resulting in a necessity for the introduction, on a larger scale, of mechanized agriculture. After the end of the war, the increase in tractor numbers became more pronounced still, with the importation of 11,142 tractors in 1950 alone, representing 70 per cent of the number already existing.

Unfortunately, from 1952 the rate of importation of this most useful agricultural implement declined dangerously for several reasons, causing serious damage to the development of agriculture. In spite of the necessity for increased mechanization of Brazilian agriculture after the war, this was still insufficient for a country depending on agriculture and having large areas at its disposal. Since it is so urgent to mechanize, the Brazilian government is again taking certain measures. Instructions were given to the Ministries of Agriculture and of Finance, committees were formed for the necessary studies and for the elaboration of projects and their financing through the Export Import Bank and also through foreign manufacturers.

Training centres were organized for tractor drivers and mechanized units were set up, as well as courses in the handling and use of modern agricultural machinery. Studies were made to determine which regions of the country have the more pronounced need for such machinery and

*Figure 1. Exhibition of farm machinery at the Luiz de Queiroz College of Agriculture, and the Agricultural Engineering building*

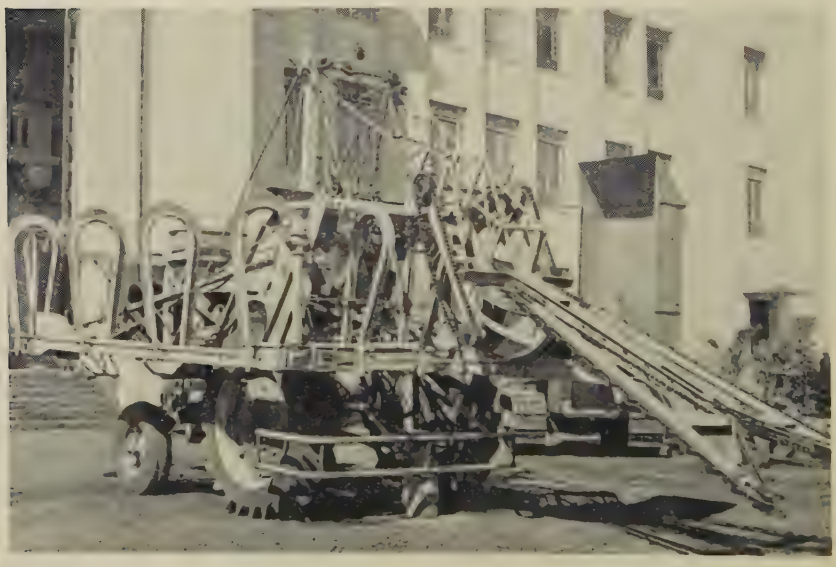

*Figure 2. Cane sugar harvester used in Brazil*

which are the types of the latter more urgently needed. The possibilities of direct sale to the farmer and the form of payment, stretched over a long period, were also considered.

At present, owing to the considerable increase in prices for farm machinery as a consequence of the high exchange value of the dollar, the Government is studying the latter question in order to find special forms of procedure which will enable an increase in the importation of tractors to the extent necessary.

*Figure 3. Mechanization of coffee cultivation*

The installation of national industrial plants to produce tractors is also being undertaken. The manufacture of tractors is the basic point, since that of other farm machinery is already at least partially under way, and the former could be easily organized. Two important undertakings are planning the production of tractors for 1957. One, the Intramag S.A., is located in Taubaté, State of Sao Paulo, and plans to produce three types of tractors, though initially the engines will still be imported: two Continental tracked models, and one Renault with wheels (Continental *CP 36*, 2·7 ton, 36 h.p., with diesel engine; Continental *CD 7200*, 13 ton, 72 h.p., with diesel engine; and Renault *R–7050*, 30 h.p., with petrol or diesel engine). The Intramag hopes to produce, in 1957, 150 Continental *CP-36* tractors, 150 Continental *CP–7200*, and 300 Renault *R–7050*. Another undertaking, Krupp, to be installed in Campo Limpo, State of Sao Paulo, plans to produce, in 1957, Lanz tractors at a rate of 200 per month. The Fabrica Nacional de Motores, in the State of Rio de Janeiro, will start producing Fiat tractors. Thus we see that various industrial enterprises plan to produce tractors in Brazil, and the manufacture of engines is at least partially under way.

The extraordinary increase of the population in Brazil, the necessity for increasing agricultural and industrial output, the transference of rural populations to the towns, all urge a rapid and complete mechanization of Brazilian agriculture, requiring both large scale importation and local manufacture of agricultural machinery.

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# *A Preliminary Investigation into the Uptake and Translocation of Phosphorus-32 in* Theobroma Cacao *L.*

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In a previous communication by Cornwell[1], techniques were studied for obtaining radioactive trees for the subsequent labelling of insects at their feeding sites under field conditions. By introducing phosphorus-32 into the trunk, it was shown that translocation from the point of application was small and that the distribution of tracer within the tree was localized. In the present work, the uptake and translocation of phosphorus-32 was investigated further, by comparing methods of trunk implantation, root uptake and application to the soil. The studies were carried out in the Gold Coast using *Theobroma cacao* L. as a preliminary to the labelling of the mealybug vectors of Swollen Shoot virus disease, whose movements both within the cacao canopy and between cacao trees are of great interest.

## EXPERIMENTAL METHODS

*Application of phosphorus-32*—The investigation was carried out in November 1955 at the end of the main wet season. The experimental area supported cacao growing under conditions typical of peasant cultivation; the area was flat, the soil covered by a rich deposit of cacao litter and there was no ground vegetation. Seven mature trees were used, growing under forest shade, and although they were close together it was not possible to select seven trees growing under identical shade conditions. The degree of exposure of the trees to sunlight was assessed on an arbitrary scale of 0 to 10, the upper limit indicating maximum exposure. Three trees were used to study trunk implantation, three for root uptake and one for soil application (*Table 1*).

Carrier-free phosphorus-32 in the chemical form of orthophosphoric acid was supplied by the Radiochemical Centre, Amersham. In preparing the active solutions, traces of carrier were added. Trunk implantations were made by inserting thin glass ampoules containing the active solutions into holes of one inch diameter. Attempts were made to drill these to the centres of the trunks. They were made at 1 ft above the ground and sloping downwards at an angle of 45°. The ampoules were broken within the holes by knocking in tight-fitting, hard-wood plugs. Root applications were made by carefully removing the soil at the base of the tree and immersing the roots in active solution contained in small corked bottles. The soil was then replaced. Soil application was made by pouring diluted,

* Formerly at West African Cocoa Research Institute.

active solution into a circular depression in the soil around the tree at a few inches from the base of the trunk. Details of the activities and volumes of active solution employed are shown in *Table 1.*

*Table 1. Details of treatments*

| *Type of application* | *Total activity applied (mC)* | *Total volume of solution (ml)* | *Degree of exposure of trees to sunlight (Scale 0–10)* |
|---|---|---|---|
| *Trunk implantation* — *1 hole* | 5·0 | 2·4 | 3 |
| *3 holes* | 2·2* | 0·5 | 7 |
| *3 holes* | 10·0 | 0·75 | 10 |
| *Root application* — *1 lateral (not cut)* | 1·2 | 120 | 3 |
| *6 laterals (cut)* | 1·2 | 450 | 3 |
| *tap root (not cut)* | 1·2 | 120 | 4 |
| *Soil application* | 1·1 | 2600 | 5 |

* One of three ampoules, each containing 1·1 mC, was not broken within the tree.

The trees were felled and assayed in the laboratory 14 days after treatment. All trees appeared healthy at the time of felling.

## METHODS OF RADIOACTIVE ASSAY

Translocation of phosphorus-32 from its point of introduction into the tree was examined by recording total activities on transverse sections of the trunk, which were cut at various elevations above the ground. The path of translocation in the trunk was located by making detailed counts on the cut ends, using a lead plate with a hole of $\frac{1}{2}$ in. diameter, through which the radiation of a particular area was measured. In one instance, the path of translocation was examined by recording counting rates on the surface of the bark. The distribution of activity in the branches was determined from a sample of ten leaves, taken at random from each branch. Ten leaves weigh about 2 gm and they were found to provide an adequate sample for the purposes of the present study. Only fully developed, mature leaves were used and counts were made with an 8 in. cylindrical glass counter placed on the back of the leaf, $\frac{1}{2}$ in. above the main vein.

## EXPERIMENTAL RESULTS

### *Uptake of phosphorus-32*

The volume of active solution translocated after treatment by trunk implantation cannot be accurately assessed. It is probable that uptake is impaired by the exudation of mucilage into the hole soon after drilling, and that phosphorus-32 is adsorbed on to the surfaces of the ampoule and the hard-wood plug. Extremely high counting rates were recorded near the holes of implantation and it was estimated that some 90 per cent of the active material remained at this level. After the trunks had been assayed, they were split open; all the ampoules had

been pulverized by knocking in the plugs, except one containing 1·1 mC, which remained intact in the tree initially implanted with 3·3 mC. Therefore, in this tree, only 0·5 ml of active solution was available for translocation from two holes.

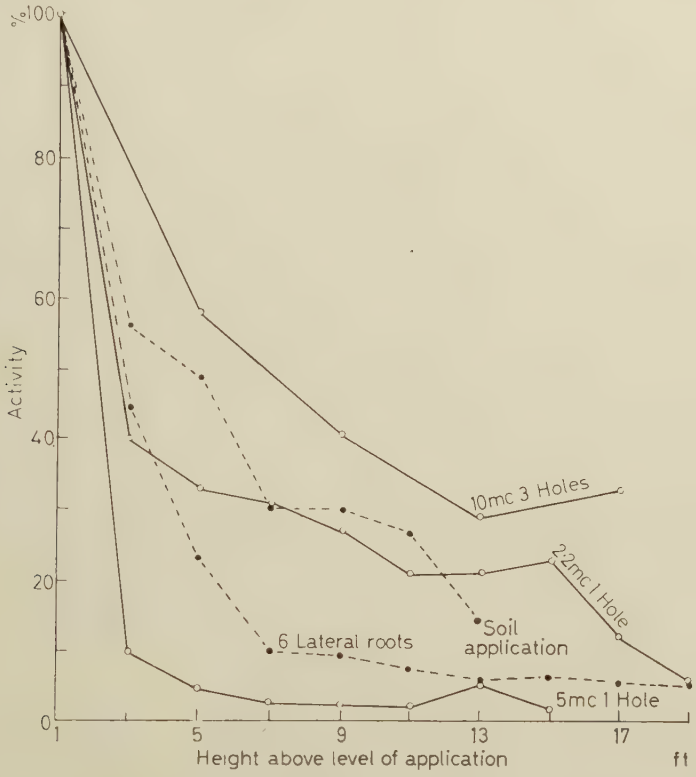


*Figure 1. Total activities recorded on transverse sections of trunk cut at various elevations, 14 days after treatment. Activities are expressed as the percentage of the radiation recorded on the section at 1 ft above the level of application*

The volumes of active solution taken up after root application were determined by measuring the volumes of solution remaining in the bottles. Assays of the residual solutions were also made. In the tree which was treated by the tap root, only the intact, terminal 2 in. of the root were immersed in active solution. This tree absorbed only 6 ml. In the tree which was treated by one lateral root, the whole length of the 4 ft root and its finer branches was immersed. This tree absorbed 26 ml of solution. The active solutions used at the initial treatment of both trees contained 10 mC/litre (*Table 1*). At the time of assay, and after correction for physical decay, there was found to be no appreciable change in the activity per unit volume of the solution used in the treatment of the tap root, but the activity of that used in the treatment of the lateral root had decreased by 0·33 mC/litre. This result suggests differences in the behaviour of the roots in their demands for phosphorus.

The tree which was treated by 6 lateral roots absorbed a total of 35 ml of solution. The six lateral roots were cut at about 1 ft from the base of the tree and they issued from the trunk in three pairs; 17 ml of solution were taken up by the two roots (branches of the same lateral root) at position ' one ' (*Figure 7*), 4 ml by two roots which issued together at position ' two ' and 14 ml by two roots arising, one a few inches above the other, at position ' three '. There were only slight differences between the concentrations of the active solutions which remained in the three vessels.

The large volumes of active solution which remained in the bottles after treatment by the immersion of roots indicate that it is difficult to obtain efficient uptake of active material by this method. In the three trees so treated, uptake per root was highest after the immersion of the intact lateral root. It was obviously not possible to measure the volume of active solution taken up by the tree which was treated by soil application. Using leaf counts as a basis for estimation, certainly more phosphorus-32 was absorbed by this tree than by those which were treated by the immersion of roots.

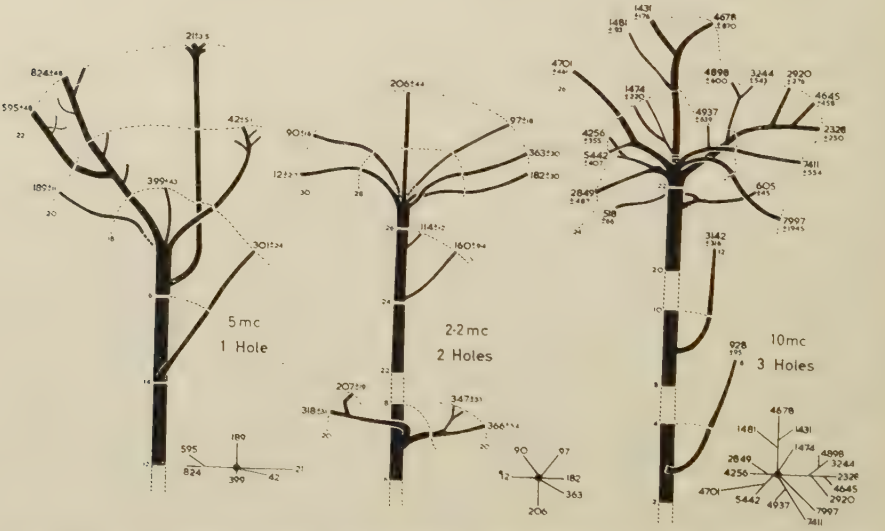


*Figure 2. The distribution of activity in the branches of trees into which $^{32}P$ was introduced by trunk implantation. Activities are represented by mean counts per minute with standard errors recorded from a sample of ten leaves per branch. Trees viewed from the ' front ' side; elevations shown in ft above ground. Plan diagrams indicate the radial distribution of activity in the branches at the jorquette*

*Activities at various levels in the trunk*

The activity recorded on each transverse section of trunk was expressed as a percentage of the activity recorded on the section at 1 ft above the level of application. For the trees which were treated by their roots and by application through the soil, the section cut at ground level was used for this purpose. This treatment of the data allowed a comparison to be made of the efficiency of translocation which took place after the various treatments had been applied. *Figure 1* shows that in all trees there was a more marked decrease in activity in the first few

feet above the basal section than at higher levels of the trunk. Increasing amounts of phosphorus-32 were translocated to the tops of the trees, in relation to the basal section, in trunks which were treated by one, two and three holes respectively. *Table 1* shows that these trees were also subject to increasing exposure to insolation. Under similar conditions of shade, application by six lateral roots resulted in better translocation than was obtained after trunk implantation by one hole. After application through the soil slightly better translocation was obtained than by introducing the phosphorus through two holes in the trunk, although the latter tree was more exposed to sunlight. Application by the tap root and one lateral root provided low counting rates, and for this reason the data were not examined.

*The path of translocation and distribution of activity in the branches*

*After trunk implantation*—The hole in the tree implanted with 5 mC penetrated to the centre of the trunk. Translocation in the trunk was examined by recording radiation through the bark. *Table 2* shows a marked localization of activity on the ' front ' surface of the trunk (the side of implantation), and indicates a deviation of the translocation stream to the ' left ' side at about 7 ft, becoming more pronounced at 13 ft above the ground. *Figure 2* shows that most of the phosphorus-32 passed into the branches arising on the front and left sides of the tree and that very little was found in the branches arising on the back and right sides. Scarcely any phosphorus was taken up by the chupon arising on the right side, although this branch contributed largely to the foliage of the canopy.

*Table 2. Counts per minute recorded on the trunk surface of* Theobroma cacao *L. implanted with 5 mC of phosphorus-32 by one hole*

| *Height above ground (ft)* | *Surface* | | | |
|---|---|---|---|---|
| | *Back* | *left* | *front* | *right* |
| 1 *level of implantation* | ∞ | ∞ | ∞ *side of implantation* | ∞ |
| 3 | 341 | 238 | *345* | 108 |
| 5 | 11 | 66 | *368* | 43 |
| 7 | 105 | 268 | *458* | 45 |
| 9 | 66 | 243 | *348* | 36 |
| 11 | 23 | 221 | *341* | 71 |
| 13 | 60 | *288* | 231 | 36 |
| 15 | 168 | *660* | 233 | 18 |

Translocation in the trunks implanted with 2·2 and 10 mC was examined by making detailed counts of the activity on the cut transverse sections. In the tree implanted with 2·2 mC, the holes penetrated almost to the centre of the trunk. *Figure 3* shows that at ground level (1 ft below the level of implantation) there were two translocation streams, but above this level only one was evident. From 2 to 6 ft above the ground, most of the activity remained localized in the tissues of the centre wood below which the ampoules were broken. At 14 ft above the ground, the phosphorous-32 became localized on the front and right sides. *Figure 2* shows that branches

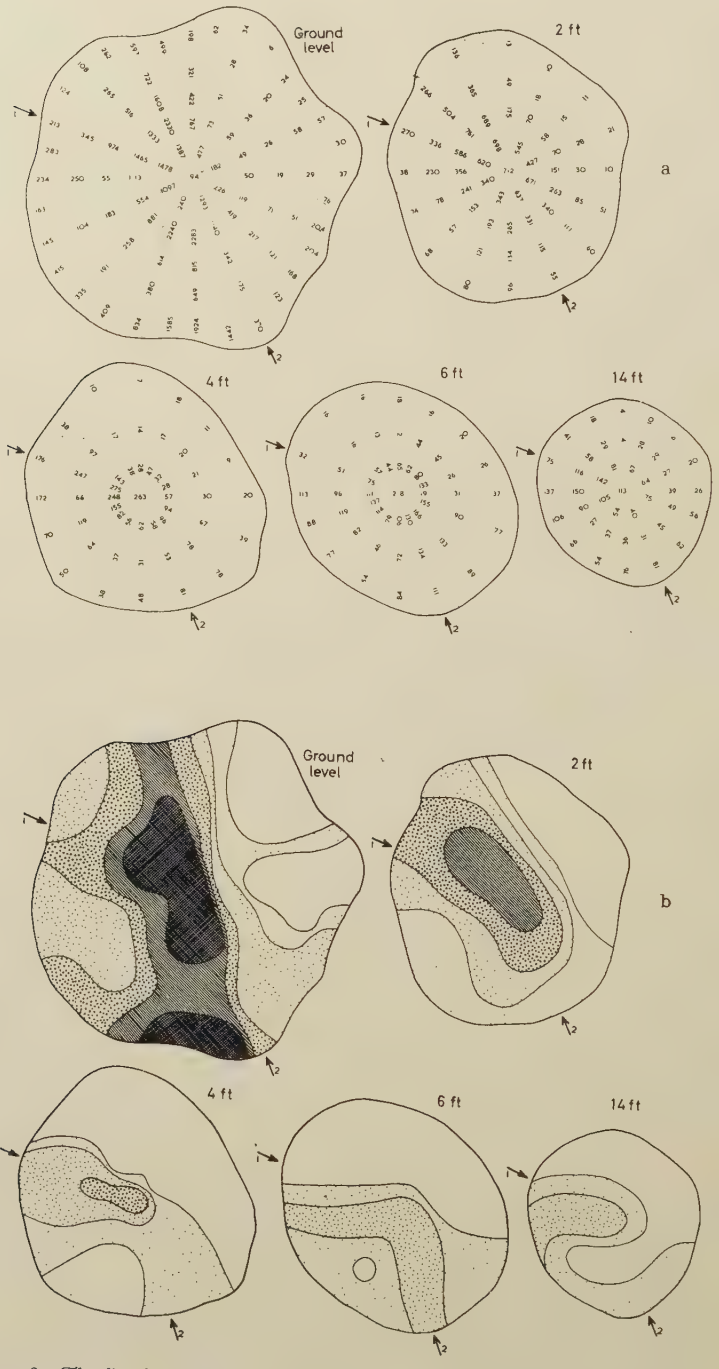


*Figure 2. The distribution of activity (c.p.m.) on transverse sections of trunk at 0, 2, 4, 6 and 14 ft above ground of the tree implanted with 2·2 mC in two holes. The positions of the holes are indicated by arrows. Hole ' one ' was made in the ' front ' of the tree*

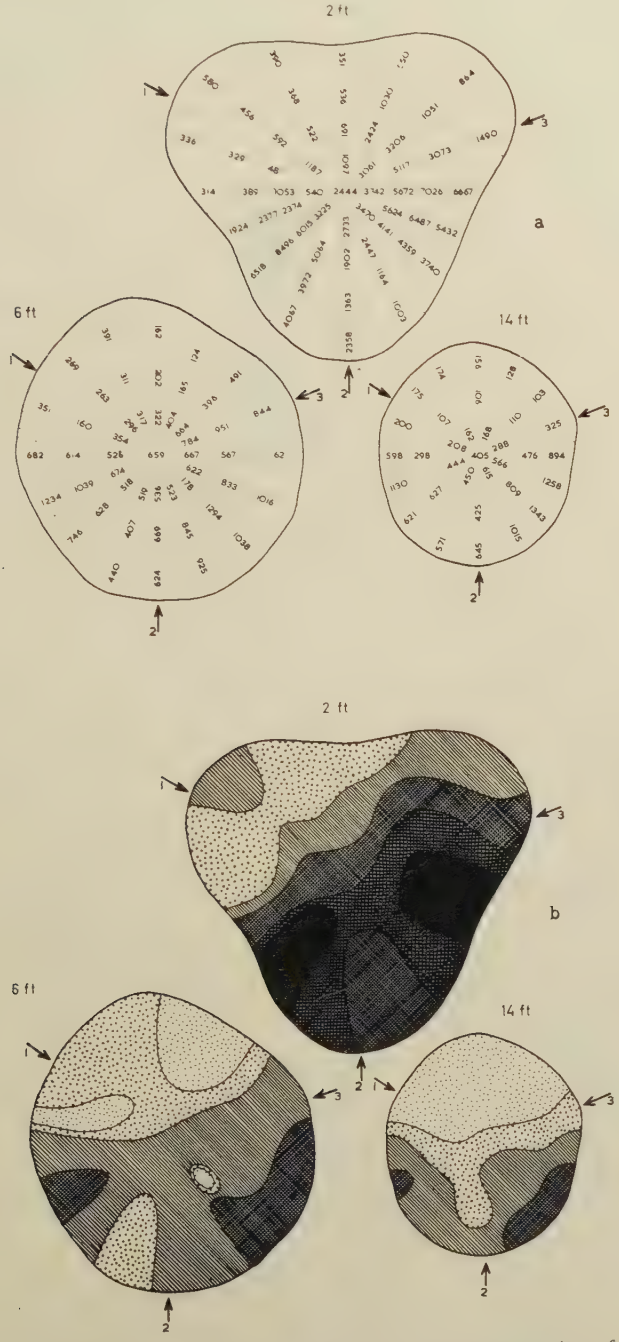


*Figure 4. The distribution of activity (c.p.m.) on transverse sections of trunk at 2, 6 and 14 ft above ground of the tree implanted with 10 mC in three holes. The positions of the holes are indicated by arrows. Hole 'two' was made in the 'front' of the tree*

arising on the front and right sides gave the highest counting rates; 207 to 366 c.p.m. at 16 to 18 ft and 206 to 363 c.p.m. in the canopy. Branches arising on the back and left sides of the trunk gave lower counting rates ranging from 12 to 97 c.p.m.

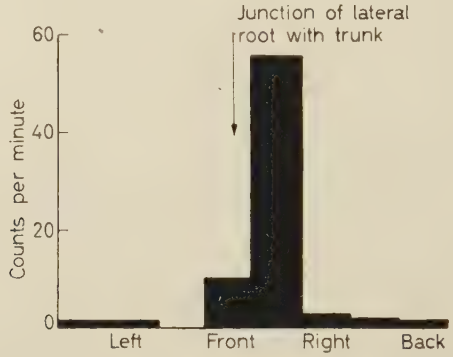


*Figure 5. Activities recorded on the ground level section of the trunk after treatment by one lateral root. The distribution of activity in an area 1 in. wide round the periphery of the section is shown in relation to the junction of the lateral root to the trunk*

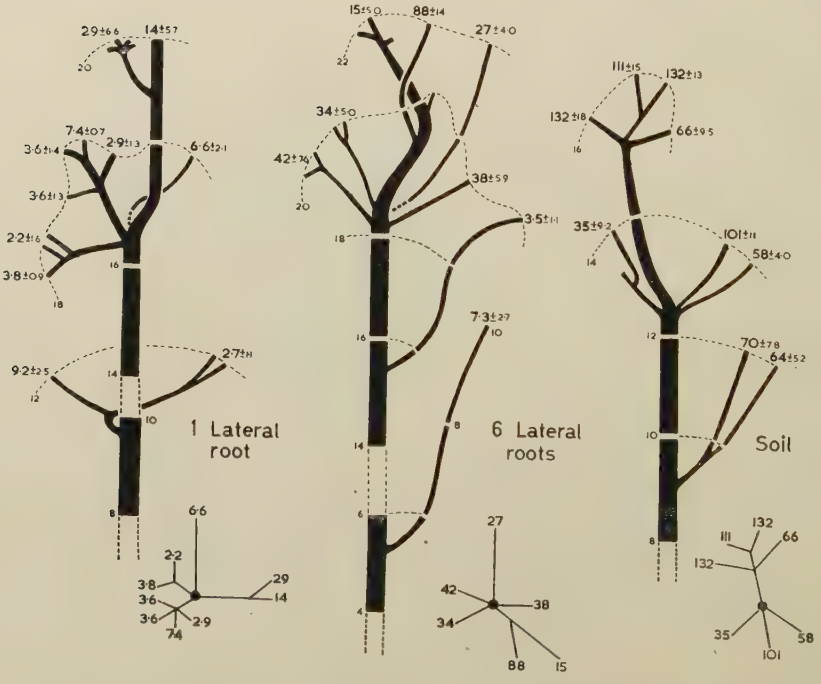


*Figure 6. The distribution of activity in the branches of trees after treatment by root and soil application. Activities are represented by mean counts per minute with standard errors recorded from a sample of ten leaves per branch. Trees viewed from the 'front' side; elevations shown in ft above ground*

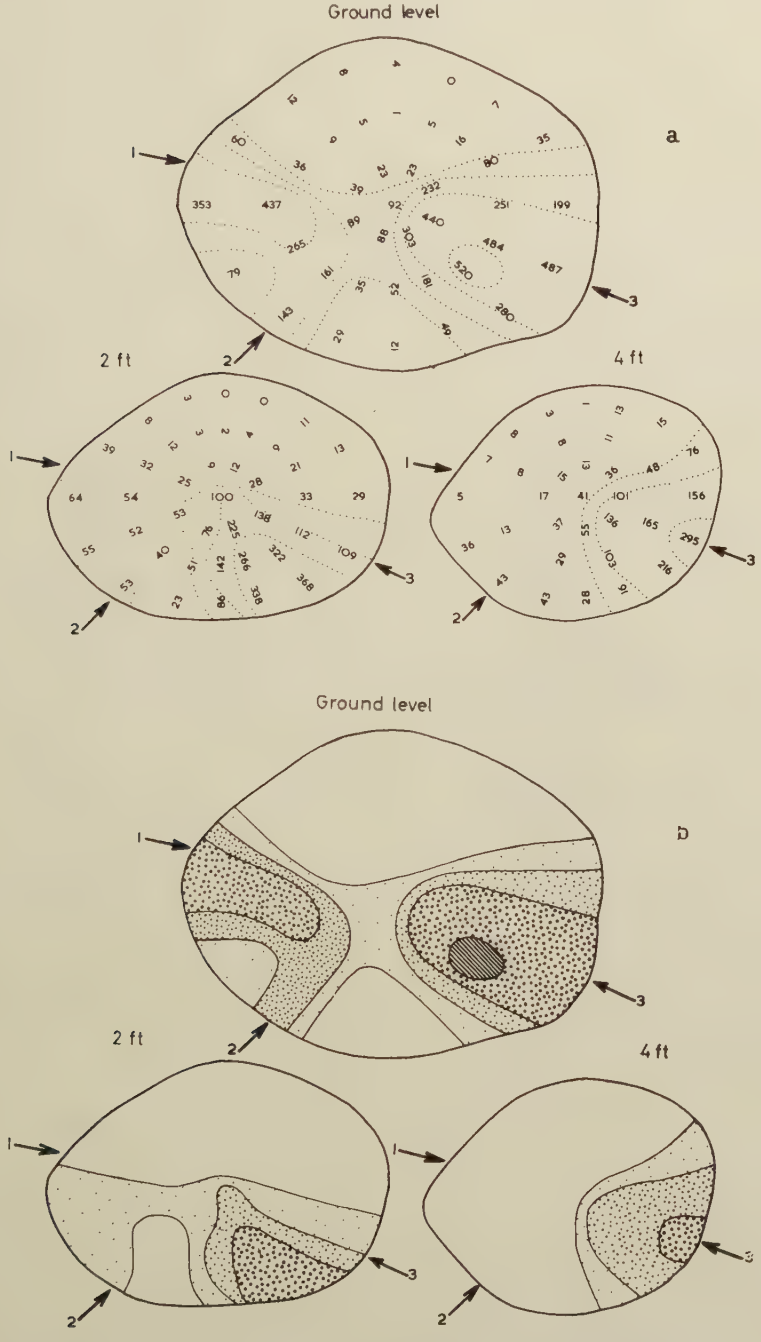


*Figure 7. The distribution of activity (c.p.m.) on transverse sections of trunk at 0, 2 and 4 ft above ground after application through 6 lateral roots. The junctions of the paired roots with the trunk are indicated by arrows. The ' front ' of the tree lies between junctions ' two ' and ' three '*

Holes made in the tree implanted with 10 mC did not penetrate to the centre wood. *Figure 4* shows that at 2 ft above the ground there were two areas of high activity on the left and right sides of the trunk, with a third area of lower activity on the left side towards the back. Higher up the tree at 6 ft, the two areas of high activity became more localized in the outer tissues of the trunk, and at 14 ft, they were confined to a small peripheral zone on the left side and a larger area at the front-right. The distribution of phosphorus-32 in the branches showed a similar pattern (*Figure 2*), with high activities present in the leaves on the left side (4000–5000 c.p.m.), lower activities in branches arising from the back (1500–4500 c.p.m.), higher activities between the back and right sides (2500–5000 c.p.m.) and the highest activities on the front and right sides (7000–8000 c.p.m.).

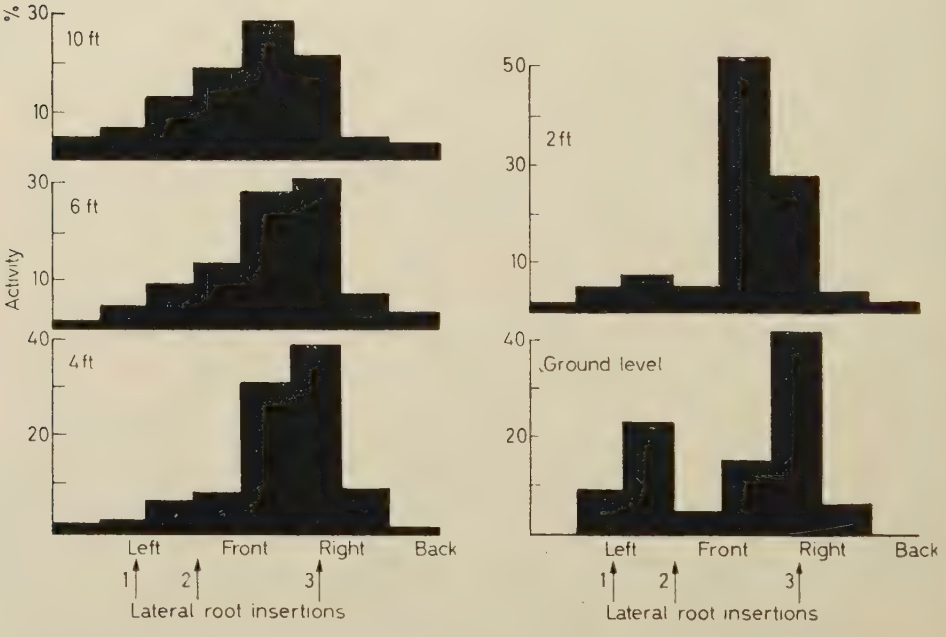


*Figure 8. The distribution of activity on transverse sections of trunk at 0, 2, 4, 6, and 10 ft above the ground after application by six lateral roots. The activities recorded in eight circular areas of 1 in. diameter around the periphery of the sections are expressed as percentages of the total activity and are shown in relation to the insertions of the paired lateral roots*

*After root and soil application*—Because very low counting rates were obtained from the tree which was treated by one lateral root, the path of translocation was examined only from the section cut at ground level. Using a lead plate with a hole of 1 in. diameter, counts were made of the radiation at eight positions around the circumference of this section. *Figure 5* shows that the tracer was localized to a very marked degree in a small area almost vertically above the root junction. *Figure 6* indicates a marked localization of activity in the branches of the canopy; leaves of all branches provided very low counting rates (2 to 9 c.p.m.), except those from the secondary chupon which gave a mean of 29 and a range of 4 to 67 c.p.m.

The path of translocation in the tree which was treated by six lateral roots was examined in greater detail. The section cut at ground level (*Figure 7*) showed that the areas of highest activity were located intermediate in position between the centre wood and the periphery of the section, directly above the junctions of the roots to the trunk. The pattern of activity on this section is largely determined by the volumes of solution taken up by the various roots. Between the ground level section and that cut at 4 ft, translocation became more localized to the front and right sides of the trunk. *Figure 8* shows that between 4 and 10 ft this zone of activity spread round the circumference of the trunk, such that the areas of high activity became less pronounced on the front and right sides than at lower levels. However, both side branches arising at 6 and 16 ft up contained little activity. Leaves from all branches above 18 ft gave appreciable counting rates and showed that the largest amount of tracer had passed into one minor branch at the top of the canopy.

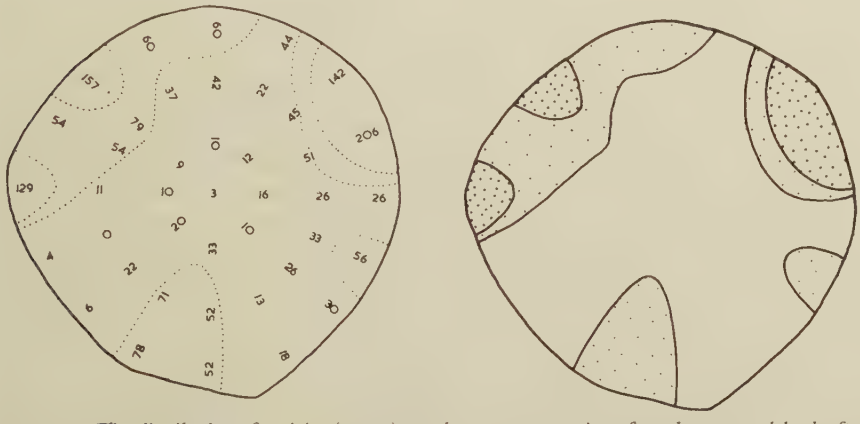

*Figure 9. The distribution of activity (c.p.m.) on the transverse section of trunk at ground level after soil application*

On the ground level section of the tree which was treated by soil application, there were five areas of activity almost equally spaced around the periphery (*Figure 9*). In comparison with the other treatments, soil application thereby provided a more uniform distribution in the trunk. This is illustrated further in *Figure 6* which shows that appreciable counting rates were obtained from the leaves of all branches, particularly those at the top of the canopy.

An assay was not made of the tree which was treated by the tap root as insufficient phosphorus-32 was absorbed.

*Passage of phosphorus-32 into cacao pods*

A cacao pod growing at 13 ft above the ground on the trunk implanted with 5 mC was assayed externally and no radiation was detected. The pod was split open and only traces of activity were detected in the beans. Two pods, which were almost mature, were removed from the canopy of the tree implanted with 10 mC. These were monitored externally and each

gave over 7000 c.p.m. Individual beans gave counts ranging from 1200 to 3000 per minute and after removing the testae these counting rates were doubled. The testae themselves contained very little phosphorus-32 and only traces of activity were located in the pulp. External monitoring of pieces of cotyledon and pod husk, of equivalent size and shape, showed that the cotyledons had taken up about six times more phosphorus than the husk. Using the same method of assay, it was shown that the green, outer layers of the husk gave three times the counting rate of the inner layers, and cotyledons gave counting rates about three times higher than the bean embryos.

*Labelling of mealybug populations*

Adult mealybugs, *Pseudococcus njalensis* Laing, were removed from the tree implanted with 5 mC. They had fed on the canopy branch from which leaves gave over 800 c.p.m. Counting rates from the bugs varied between background and 16 c.p.m. No activity could be detected in the immature stages. Mealybugs were also removed at random from twigs of the tree implanted with 10 mC. Adult bugs gave counts ranging from 15 to 379 with a mean of 116 c.p.m. Second and third instar nymphs gave a mean counting rate of 9 c.p.m. and a range from background to 20 c.p.m. Ants, *Crematogaster striatula* Emery, attending the mealybugs on these trees gave counting rates which were two or three times higher than those obtained from the adult mealybugs. This indicated that the ants had imbibed appreciable quantities of radioactive honeydew and that they had accumulated phosphorus-32 to a greater extent than their hosts. A similar result was obtained by R. C. Pendleton and A. W. Grundmann[2] with various ants attending a species of *Anuraphis*.

## DISCUSSION

The literature on methods of tree injection has been summarized by R. F. Morris[3]. Translocation problems in relation to disease have been studied by introducing iodine-131 into Oak[4], and calcium-45 and phosphorus-32 into White Pine[5]. Calcium-45 and rubidium-86 have been used to investigate translocation in healthy and decadent Yellow Birch and in White Pine[6]. P. J. Kramer and K. M. Wilbur[7] used phosphorus-32 in their studies of mycorrhizal roots, and W. R. Stanton and W. K. Sinclair[8] describe experiments on the uptake and translocation of phosphorus-32 in plum. Investigations using insects labelled with radioisotopes have usually involved the artificial release of such insects in the field[9–11]. Pendleton and Grundmann[2], however, have used phosphorus-32 to study the complex of insects associated with Thistle by labelling the host plant in the field.

The extreme variability in the growing conditions of farmers' cacao prevents a statistical appraisal of the results of the present study. Futhermore, it must be emphasized that the movement of phosphorus-32 was arrested by felling the trees 14 days after treatment and it cannot, therefore, be assumed that the active materials passed directly from the point of application to the locations determined at the time of assay, or that more uniform distributions of tracer might not have been obtained if the trees had been

felled after a longer period. In addition, although it may seem desirable to try to estimate from the data absolute levels of activity in various parts of the tree, this has not been possible because of the methods of assay employed; such complications as absorption, sources of unknown depth in the trunk, and counter efficiency in relation to size of window and distance from the source prevent this.

The introduction of phosphorus-32 by trunk implantation into *Theobroma cacao* L. has confirmed the results previously obtained with *Pseudotsuga taxifolia* (Poir) Britt., Cornwell (l.c.) which showed that translocation of the active material away from the point of application is small and localized. To what extent uptake from the hole is impaired by mucilage, or by local damage to the tissues resulting from drilling or from the extremely high concentrations of 2·1 to 12·5 mC/ml used in these studies is unknown. Poor uptake and localized distributions were also obtained after root application; comparing the treatments employed, the results would suggest that lateral roots may make greater demands for phosphorus than the tap root and that uptake of the solution is more efficient when the lateral root is not severed. The most uniform distribution was obtained after application through the soil (*Table 3*).

It is evident that the movement of phosphorus in the trunk of cacao takes place in quite a deep band of xylem tissues. There is little lateral movement in these conducting vessels so that only those branches which originate near the vessels engaged in the translocation of phosphorus-32 may take up the active material. Uniform distribution of activity in the branches can only be obtained therefore when all the conducting vessels are actively taking part. The results suggest that this ideal is most likely to be obtained after application through the soil.

The technique of labelling insects internally with radioisotopes offers distinct advantages compared with the more widely used method of marking insects with paint. When it can be shown that the level of activity employed is below that likely to cause radiation damage, the technique permits the labelling of insects which are too small to handle and provides permanent marking throughout development, although the insect may moult several times before reaching maturity. Furthermore, the labelling of an insect at its feeding site obviates the need for its capture, removal from its environment and subsequent release. These aspects are of particular importance in the present instance, since the early stages of the mealybug vectors of cacao viruses are very small, they pass through three moults before reaching maturity, and the purpose of marking the insects is to assist in studies of their normal movements.

The results have shown that radioactivation of whole cacao trees with the subsequent labelling of mealybugs at their feeding sites can be achieved, but that higher levels of activity of the order of 10 or 20 times those employed in the present work are required in the branches before such insects can be used in ecological studies. The results have also shown that a uniform distribution of tracer within the tree is difficult to obtain; it must be pointed out that whilst this is not essential for the labelling of an insect population, it is, nevertheless, desirable. The presence of a labelled insect on a tree adjacent to a radioactive host indicates that movement from one tree to

the next has taken place. Similarly, the presence of a mature, but non-radioactive insect on a wholly radioactive host would indicate movement in the other direction. Moreover, in the interest of efficiency, the technique is directed at labelling as many insects as possible, particularly as mealybug populations on individual trees are usually low.

The results of the present work are of further interest in relation to

*Table 3. Summary of results*

| *Treatment* | *No. of paths of translocation in the trunk* | *Ratio of lowest to highest branch counts from leaf sample* | *Mean leaf count for whole tree* (c.p.m.)* |
|---|---|---|---|
| 5 *mC; 1 hole* | 1 ? | 39 | 272 |
| 2·2 *mC; 2 holes* | 1 (2 *at some levels*) | 30 | 185 |
| 10 *mC; 3 holes* | 2 | 15 | 3143 |
| 1 *lateral root* | 1 (*at ground level*) | 13 | 6·4 |
| 6 *lateral roots* | 1 (*above 2 ft*) | 25 | 27 |
| *Soil application* | 5 (*at ground level*) | 4 | 82 |

* A square-root transformation of the data was used to calculate mean leaf counts for whole trees.

the application of systemic insecticides. Studies have been made[12,13], in which various compounds were introduced into cacao trees to determine their toxic effect on the vectors of cacao viruses. The methods which these workers used to apply *Dimefox*, the most promising organo-phosphorus insecticide, were essentially similar to those used in the present work to introduce phosphorus-32. It was shown that by watering *Dimefox* on to the soil in a small depression around the base of the trunk, a uniform kill of the vectors on all branches could be obtained. Introduction of the insecticide into one hole in the trunk, however, provided an uneven kill of mealybugs; ' the greatest reduction of mealybugs occurred on those branches directly above the bore hole, the smallest reduction being found on branches originating from a point on the trunk opposite to the bore hole '. Furthermore, after application of the insecticide by three holes, live mealybugs remained on only one or two branches. If these results are considered in relation to the distributions of phosphorus-32 obtained in the present work, it will be seen that the relative toxic effects observed are immediately explicable by the effect of the method of application on the subsequent translocation of the insecticide. Whilst the fate of insecticides introduced into cacao may be assessed indirectly by their toxic effect on the mealybug population, the present work has shown that the use of phosphorus-32 promises to be of considerable value in studying, directly, the relative efficiencies of methods of application in studies of this type. In this connection, the present work has shown that the conducting vessels most actively engaged in translocation in the trunk are located peripherally, except at ground level where the translocation stream passes from the lateral roots into conducting vessels which are more deeply placed. More efficient translocation of insecticides implanted into the trunk is likely to be obtained, therefore, if the holes of implantation are made at ground level instead of at higher elevations.

In the present work the distributions of activity were so largely influenced by the methods of application that critical examination of the effect of

sunlight could not be made. The results have shown, however, that larger amounts of phosphorus-32 were translocated to higher levels in the trunks in relation to an increase in the number of holes and to greater exposure to sunlight. Furthermore, the results summarized in *Table 3* indicate an increase in the mean leaf count, per millicurie of phosphorus-32 applied, from 54 to 84 and 314 c.p.m., respectively. Implantation by one and two holes resulted, in both cases, in one main translocation stream in the trunk, whilst implantation by three holes produced two streams. Corresponding improvements in the uniformity of distribution in the branches of these trees are indicated by a decrease in the ratio of lowest to highest branch counts from 39 to 30 and 15. The marked increase in counting rates compared with the much smaller improvement in the distribution of the tracer would suggest that exposure to sunlight may be an important factor influencing the uptake of phosphorus-32 from its point of application. It seems likely, therefore, that the semi-shaded conditions under which cacao is grown in the Gold Coast, providing a pattern of light and shaded areas on the branches, may also influence the pattern of radioactivity in the tree.

Finally, the results have shown that quite low levels of activity applied to the soil are sufficient to label the aerial parts of the tree. In the present example, the mean leaf count obtained after soil application, and after correction for the level of activity applied, was a quarter of that obtained after implantation by three holes. This is surpisingly high, since the former tree was subject to lower insolation and it was anticipated that considerably more than 75 per cent of the phosphorus-32 would be retained in the soil. Although the application of phosphorus-32 to various roots provided distributions and levels of activity in the trees quite unsuitable for the purpose of labelling insects, nevertheless the results showed that the use of tracer techniques is likely to be of value in studies of root behaviour in relation to the uptake of labelled nutrients.

## SUMMARY

Phosphorus-32 was introduced into cacao trees by trunk implantation, the immersion of roots and application to the soil.

Radioactive assay showed that the distribution of activity in the trunk and branches was influenced by the location of the holes of implantation and of the roots engaged in absorbing the active material. There was little lateral movement in the conducting vessels of the trunk so that only those branches which originated near the path of translocation took up phosphorus-32. It would appear that the most uniform distribution of activity in the trees is obtained after application to the soil.

The distributions and levels of activity in the branches are considered in relation to the suitability of these techniques for labelling the mealybug vectors of cacao viruses at their feeding sites in the field. Considerably higher levels of activity than those employed in the present work are required in the branches before such insects can be used in ecological studies. The results are of further interest in relation to other fields of cacao research, involving the application of systemic insecticides, the uptake of nutrients and the effect of shade.

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# *Hybridization of Rice*

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The following note on the technique of hybridization of rice used at the West African Rice Research Station has been prepared as the method has proved effective and differs in many respects from methods previously published.

Techniques of emasculation such as those described by N. B. Mendiola[1] and J. J. Niles[2] involve the clipping of the glumes and this necessitates the germination of the seed produced on nutrient agar. The hot water method developed by N. E. Jodon[3] suffers from the disadvantage that the straw is easily broken below the panicle when it is bent over. The use of paper envelopes as developed by K. Ramiah[4] did not give good results in Burma and Rhind's technique is a development from this. A similar technique is now in use in Malaya[5] and it is also understood in other East Asian countries[6], but does not appear to have been published.

From a few observations that were made in 1951 it appears that natural opening of spikelets occurs at Rokupr when the temperature reaches 83° to 85°F. This is normally between 9.30 and 10.0 a.m. suntime. The best time for emasculation is therefore between 8.30 and 9.30. Earlier than this there is poor response to treatment and after this natural opening has started and the anthers dehisce before they can be removed. During periods when the dry harmattan wind is blowing, which may occur during flowering of the longer duration varieties, morning temperatures and humidities are lower and natural opening of the spikelets may occur as late as mid-day. When this occurs artificial hybridization is more difficult, the anthers dehiscing very soon after the spikelets open.

Records taken in 1951 show that on 28 November—a day of slight harmattan—natural opening of spikelets occurred at 10.30 a.m. when the temperature was 84°F and relative humidity 78 per cent. On 11 December when the harmattan was stronger spikelets opened at 11.30 a.m. The temperature was then 85°F but the relative humidity only 50 per cent (see *Figure 1*).

## EMASCULATION

The method of forcing flowering developed by Rhind depends upon surrounding the panicle with hot saturated air, and full details of the practice as carried out at Rokupr are as follows. Water at 43°C is carried to the field in a vacuum flask. A panicle is chosen for the female parent and all the spikelets that have flowered previously are cut off with a fine pair of scissors. The absence of the stamens in these spikelets is easily seen when the panicle is viewed against the light. As found by other workers, panicles in the third day of flowering give the greatest number of spikelets which respond to forcing. After a little experience these panicles are soon picked

out by observing the number of spikelets which have already flowered. A little of the warm water is poured into an empty vacuum flask, shaken up and emptied out. The flask is then inverted over the panicle and held with the fingers across the mouth, thus closing it. The flask is kept in position for from one to three minutes, though the exact time must be determined by inspection. On inspecting the panicle after a short time it is found that several spikelets have opened and that the stamens are hanging out. The flask is now removed and the anthers pulled from the open spikelets with a pair of fine forceps. It is found that a number of spikelets open shortly after removal of the flask and if the panicle is held bent to one side the stamens of these all come out together and can be removed in one operation. The stamens are usually removed by their filaments though if

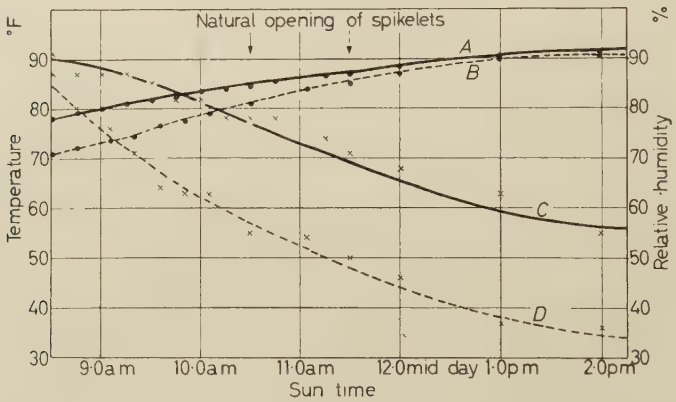


*Figure 1. Temperature: A 28 November 1951; B 11 December 1951; relative humidity; C 28 November 1951; D 11 December 1951*

only the anther is approachable a firm but light grip on this will enable it to be pulled away without dehiscing. Contrary to reports from other workers it is found best to start at the bottom of the panicle and work towards the top—both in emasculation and pollination. By doing this the spikelet under attention can be supported firmly without damage to those not yet dealt with.

As emasculation is best carried out as quickly as possible no special attempt is made to count the anthers as they are removed from each spikelet. If any are left inside the glumes a gentle beating of the panicle on the palm of the hand after all visible anthers have been removed will dislodge them and they can be pulled off. All unopened spikelets are then cut off. It may be found at this stage that there are further spikelets just opening. It is seldom worth while emasculating these as in most cases it is found that dehiscence of some of the anthers has taken place or does so immediately the spikelet is handled. The emasculated spikelets are then examined with a hand lens and any whose stigmas show signs of pollen are cut off.

## POLLINATION

A number of pollination techniques were tested before a satisfactory one was found. These were briefly:

(*a*) Removal of anthers from male parent by pulling open the glumes and transference to a Petri-dish before emasculating the female parent—it was difficult using this method to find ripe undehisced anthers to use;

(*b*) Pollination by means of a camel-hair brush from ripe anthers dehiscing in a Petri-dish—the pollen did not stick well to the brush which was itself difficult to insert between the glumes;

(*c*) Anthers removed from naturally opening spikelets of the male parent —it was found that the spikelets of the female parent, emasculated and bagged previously, had all closed and pollination was difficult;

(*d*) Forcing opening of the spikelets of the male parent in a vacuum flask, and applying the anthers directly to the emasculated spikelets—it was difficult to choose anthers in the right stage of ripeness and to prevent them dehiscing too soon, but a slight modification was introduced and gave a successful technique, the details of which are as follows. While the panicle of the female parent is inside the vacuum flask one or two panicles of the male parent, in their third day of flowering if possible, are picked and when the flask is removed from the female parent are placed inside it being held in position by the inserted cork. The temperature of the flask is still sufficient in normal weather. During harmattan weather it was found necessary, however, to pour a little more warm water into the flask, shake up and leave at the bottom of the flask while the panicles of the male parent were being treated. The panicles remain inside the flask during emasculation, removal of unopened spikelets and examination of the female parent. They are then removed and it is found that a fair number of spikelets have opened and their stamens are hanging out. The stamens are promptly removed with a pair of fine forceps into a lidless 2 in. Petri-dish or watch glass taking care to handle them by their filaments. This dish can be held conveniently in the palm of the left hand leaving the fingers free to support the spikelets during pollination. Ripe anthers are immediately obvious by their lighter colour and swollen appearance and they are picked up by one end in the forceps and held inside the glumes of the emasculated spikelets. Tapping of the forceps on the edge of the lemma is sufficient to cause the anther to dehisce and shower pollen on to the stigmas when the empty anther sac can be removed. In the case of one variety used, *Kav. 12* (a selection from the Indian rice *Kavunginpoothala*), the stigmas protrude between the glumes as soon as the spikelets open and it is necessary with rices that behave in this manner to rub the anther sacs on the stigmas as the pollen released inside the glumes does not always reach them. Even so the percentage of setting is lower than with other varieties. Examination with a lens shows well pollinated stigmas, though this examination has been omitted from the routine as it is not absolutely necessary and takes up valuable time.

After pollination the plant is labelled and the panicle enclosed in a cloth bag for 24 hours. Between all operations the Petri-dish or watch glass, scissors and forceps are sterilized with a flame from a spirit lamp.

By using this method of forcing opening of the glumes up to 41 spikelets on a single panicle have been emasculated and the proportion of obvious selfing (as determined by inspection of the stigmas) is usually less than 10 per cent. With the final pollination technique an average of 74 per cent of the spikelets pollinated set seed, omitting the cross that had *Kav. 12* as the female parent. With this cross, where as previously mentioned pollination was difficult, a 35 per cent set was recorded. On germination and growing of the cross pollinated seed just under 8 per cent showed characters similar to the female parent and were assumed to be self-pollinated.

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# *The Problem of Milk Production in Tropical Countries—I. Introduction*

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Milk for direct human consumption and for manufacturing milk products is obtained from many kinds of domestic livestock, but approximately 90 per cent of the world's supply is produced by various types of domestic cattle[1]. The proportion of the total milk produced by domestic livestock other than cattle is probably higher in tropical than in temperate countries, but in tropical countries cattle undoubtedly still produce most of the milk. In this study only problems of the production of milk by cattle in tropical countries will be considered.

That milk production in tropical countries is a particularly difficult problem is widely recognized. According to T. W. McCabe[1] the world only produced enough milk to meet 60 per cent of the world population's mimimum dietary needs in 1953, but there were surpluses in some areas and shortages in others, as countries in the temperate zone containing 40 per cent of the world's population produced 85 per cent of the world's milk. In fact in temperate countries there was an average of more than 500 lb. of milk per head available, while in tropical countries there was only about 60 lb. This is, of course, only the overall picture, as there were areas in the temperate zone with a low and areas in the tropical zone with a higher milk production, as can be seen from *Table 1* and *Figure 1*. These local variations are often due to local dietary and agricultural customs or to special political and social reasons, and are not necessarily due to the inherent problems of milk production.

It could be argued that if the production of milk presents particularly difficult problems in the tropics, then the simplest solution would be to increase production in the temperate zone and distribute the surplus as condensed, evaporated or dried milk in tropical countries. The fact is that, even if the economic and political problems of distributing surpluses on a world scale could be solved, and they are far from solved, there are other very good reasons why a dairy industry should be encouraged in most tropical countries. Until recently most farming in tropical countries has been either large scale plantation or small scale subsistence farming. Large plantations, though in some ways efficient, are often politically and socially undesirable, and subsistence farming is usually both inefficient and socially undesirable. In the past both systems have encouraged exploitation of soil resources, and it is now generally agreed that it is desirable to introduce some form of mixed farming in many tropical countries. Milk production can be readily associated with mixed farming and the efficient milk producer

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can often obtain a relatively high income from a comparatively small farm.

The problems of milk production in the tropics are complex and include social and political, as well as ' technical ', problems. This paper will only be concerned with the ' technical ' problems.

*Table 1. Estimated total milk production and production* per capita *in temperate and tropical climatic areas (after McCabe*[1]*)*

| *Area** | *Total milk production lb.* $\times 10^6$ | *Population* $\times 10^6$ | *Production* per capita *lb.* |
|---|---|---|---|
| *Temperate* | | | |
| *North America* | 138,067 | 174·9 | 789 |
| *South America* | 15,123 | 26·9 | 562 |
| *Western Europe* | 202,228 | 305·9 | 661 |
| *Eastern Europe* | 39,257 | 88·4 | 444 |
| *U.S.S.R.* | 57,025 | 205·0 | 278 |
| *Asia* | 6,220 | 126·8 | 49 |
| *New Zealand* | 11,748 | 2·0 | 5,874 |
| *Tropical* | | | |
| *Central America* | 1,080 | 9·4 | 115 |
| *Caribbean* | 2,201 | 16·9 | 130 |
| *South America* | 15,163 | 90·2 | 168 |
| *Africa* | 5,191 | 111·7 | 46 |
| *Asia (excluding India)* | 2,262 | 164·0 | 14 |
| *India*† | 42,360 | 367·0 | 115 |
| *Oceania (Islands)* | 145 | 2·7 | 54 |

* Data for Mexico, countries north or south of the tropics in Africa, the Middle East countries, Pakistan, China, Australia and certain minor territories have been excluded as these countries either have a sub-tropical climate or they are in both the temperate and tropical climatic zones.
† India has been included because, although part of the sub-continent has a sub-tropical, a major part has a tropical climate.

Low production is due to an interaction of climatic, disease, breeding, feeding, and management problems, and these vary in their importance from country to country and from region to region. A brief survey of the relative importance of these individual problems will be made in this introduction, and the climatic, breeding, feeding and management problems will be discussed fully in the three later parts of this paper.

## CLIMATE

Climatic problems are particularly complicated as climate itself is a complex of so many variable factors, and it has both a direct and an indirect effect on dairy cattle. The tropical and sub-tropical zones of the world are shown in *Figure 2*, and in general we may distinguish two major types of tropical climate, humid and arid.

In the humid tropics there is little seasonal or diurnal variation in temperature, and a high rainfall (*Table 2*), usually accompanied by high humidity. Although a great deal more is known as to the direct effect of climate on temperate type (*Bos taurus*) than on tropical type (*Bos indicus*) cattle, it is agreed that both types are affected by high environmental temperatures[2], though not to the same degree. Evidence on the effect of high humidity is conflicting, undoubtedly high humidity slows down heat loss by evaporation, but under natural grazing conditions it also reduces the radiation heat load as it is usually associated with cloudy conditions and the water vapour in the atmosphere absorbs radiation from the sun even if the skies are clear.

In the arid tropics there may be quite wide seasonal and diurnal variations in environmental temperature (*Table 2*) and the nights are often relatively cold. Thus although cattle are exposed to higher temperatures and to more solar radiation in the daytime than they are in the humid tropics, they are

*Figure 1*

able to obtain some relief from the high temperatures at night and evaporative cooling is more effective during the day. It is therefore generally considered that on balance the humid tropical climatic environment is more adverse in its direct effect on dairy cattle than the arid.

The indirect effects of climate on dairy cattle are mainly the result of the effect of the climate on forage production and the incidence of disease. With proper husbandry large amounts of forage can be produced all the year round in the humid tropics, but care has to be taken to ensure the maintenance of soil fertility, because when tropical rain-forest is cleared for pasture, the heavy rain rapidly leaches out the soil.

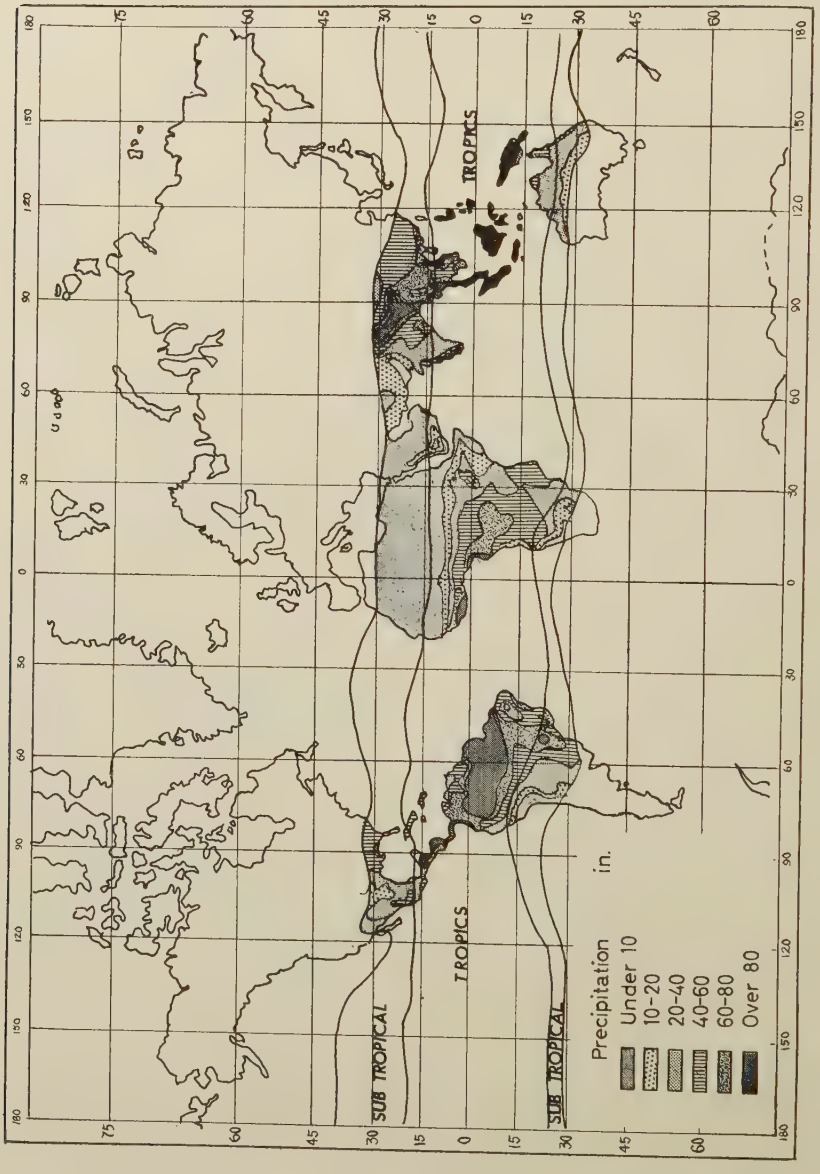


*Figure 2*

Forage supplies are more difficult to ensure in the arid tropics, as there are often long dry periods, so that forage conservation is of paramount

importance. The humid tropical climatic environment is ideal for the growth and spread of parasites, so that special precautions against parasites must be taken.

It is no accident that at the present time the majority of cattle in the tropics are raised in the arid zone. The direct effect of climate is probably not so adverse, parasitism is not such a problem and forest does not have to be cleared to provide pasture. If, however, the direct effect of climate can be ameliorated, and parasitism brought under control, it is likely that milk production will expand more rapidly in the humid than in the arid tropics as large quantities of feed can be grown throughout the year.

*Table 2. January and July mean temperatures, temperature range, and average annual rainfall at representative stations in the arid and humid tropics*

| *Station* | *Latitude* | *Temperature °F* | | | | *Rainfall in.* |
|---|---|---|---|---|---|---|
| | | *Mean* | | *Range* | | |
| | | *Jan.* | *July* | *Max.* | *Min.* | |
| *Aden, Arabia* | 12 45 N. | 76·2 | 88·1 | 109 | 61 | 2 |
| *Berbera, B. Sòmaliland* | 10 27 N. | 76·8 | 98·0 | 117 | 52 | 2 |
| *Khartoum, Sudan* | 15 37 N. | 72·0 | 90·2 | 117 | 41 | 5 |
| *Timbuctu, F.W.A.* | 16 46 N. | 71·2 | 90·9 | 122 | 41 | 8 |
| *Dakar, F.W.A.* | 14 40 N. | 70·4 | 82·3 | 104 | 55 | 20 |
| *Derby, Australia* | 17 18 S. | 86·1 | 71·5 | 114 | 42 | 26 |
| *Accra, Ghana* | 5 33 N. | 80·6 | 76·9 | 95 | 59 | 27 |
| *Hyderabad, India* | 17 20 N. | 72·0 | 80·4 | 112 | 47 | 31 |
| *Kingston, Jamaica* | 18 10 N. | 76·9 | 81·9 | 98 | 57 | 32 |
| *Dar es Salaam, Tanganyika* | 6 49 S. | 81·8 | 74·2 | 95 | 60 | 43 |
| *Darwin, Australia* | 12 28 S. | 83·4 | 77·8 | 104 | 56 | 61 |
| *Jakarta, Indonesia* | 6 11 S. | 78·7 | 79·4 | 96 | 66 | 72 |
| *Saigon, Indochina* | 10 47 N. | 79·5 | 81·3 | 104 | 59 | 79 |
| *Colombo, Ceylon* | 6 54 N. | 79·5 | 81·3 | 97 | 62 | 80 |
| *Ocean Island,Gilbert Islands* | 0 52 S. | 82·2 | 82·0 | 96 | 68 | 81 |
| *Belem, Brazil* | 1 27 S. | 79·4 | 80·2 | 95 | 64 | 93 |
| *Singapore, Malaya* | 1 18 N. | 79·8 | 81·4 | 97 | 66 | 95 |
| *Suva, Fiji* | 18 8 S. | 79·9 | 73·6 | 98 | 57 | 112 |
| *Apia, Samoa* | 13 48 S. | 79·6 | 77·2 | 96 | 61 | 118 |
| *Colon, Panama* | 9 22 N. | 75·2 | 80·4 | 95 | 66 | 127 |
| *Freetown, Sierra Leone* | 8 30 N. | 81·5 | 79·0 | 101 | 61 | 157 |
| *Debundja, Nigeria* | 4 5 N. | 78·8 | 75·4 | 92 | 64 | 400 |

## DISEASE

The incidence of both temperate and tropical disease varies widely from country to country. At one extreme there are island territories such as Fiji where there are no known tropical and few temperate cattle diseases, while at the other there are territories in Africa where a high incidence of disease of all kinds prevents the establishment of an economic dairy industry.

Disease is not, however, a limiting factor in most tropical countries. Australia, the Pacific Islands, some islands in the East Indies, the southern part of North America, and the Caribbean area are relatively free of disease, while it is not of paramount importance in Central America, and the northern part of South America. Disease is widespread in many parts of Africa and South East Asia but is being gradually brought under control and at present only partially limits production in most territories.

Conditions are ideal for the growth and spread of internal parasites in all parts of the humid tropics, but they can be controlled by a combination of good husbandry and the judicious use of drugs.

## BREEDING

In the past the introduction of high-producing temperate type cattle into tropical countries, either as purebreds or in order to grade up indigenous stock, was considered a panacea for the low productivity of dairy cattle in the tropics. Time has shown this policy to be a complete failure, and many authorities now suggest that the only possible policy that can replace it is one that concentrates on improving the production of indigenous cattle, utilizing breeding techniques that have been evolved in the temperate zone. This policy could not be carried out in many tropical countries, simply because there are no indigenous cattle. In Australia and the Pacific Islands a large number of temperate type and a small number of tropical type cattle have been introduced during the last one hundred and fifty years, while in the southern part of North America, Central America, the northern part of South America and the Caribbean, temperate type cattle were first introduced some four centuries ago, and both temperate type and a small number of tropical type cattle are still being introduced, so that the local cattle are not truly indigenous. In addition, there are relatively few indigenous cattle in many humid tropical countries in South East Asia.

There can therefore be no single breeding policy that is applicable in all tropical countries, but all over the tropical world the value of local breeding policies should be re-assessed with special reference to the new physiological knowledge on the reaction of cattle to climatic stress. It has been shown at several centres[2] that cattle are best acclimatized to the cold temperate climatic regions of the world. It may therefore be a very difficult task to raise the productivity of indigenous tropical cattle to the level of temperate type cattle in the temperate climatic zone as tropical type cattle may appear to be acclimatized to a tropical climate partly because they are relatively unproductive, though of course they are better acclimatized than temperate type cattle to drought conditions and to tropical diseases and parasites.

It may also be possible to utilize other species of the *Bos* genus that may possess useful genes that could be used in the breeding of animals that are productive in both the arid and the humid tropics. So far little or nothing has been done to explore the possibility of using other species.

## FEEDING

Nutritional standards for dairy cattle have been devised almost entirely in temperate countries and have then been applied to the feeding of dairy cattle in the tropics. As the climatic environment directly and indirectly affects feeding, it is likely that errors have been made in applying temperate zone feeding standards indiscriminately in the tropics. It is essential that feeding standards should be devised for the climatic environment in which they are to be applied.

Climatic environment directly affects the appetite of dairy cattle[3], it may affect their nutritional needs, as it undoubtedly does in the case of water requirements[4], and it could possibly affect the functioning of their digestive tract, though nothing is known of this subject.

Indirectly the climatic environment may affect the nutritive value of forage. There is evidence that the quality of typical tropical forage is low[3]. The majority of tropical forage plants mature quickly, and as the crude fibre content increases and the crude protein content decreases with maturity, the nutritional quality of tropical forage rapidly declines with age. There is some evidence that immature tropical forage has as high a nutritional value as rather more mature temperate zone forage[3], so that the provision of high quality forage in the tropics may be essentially a management problem. As the accepted methods of pasture management have also been imported into tropical countries from the temperate zone, it can be assumed that it is essential to work out modifications of temperate zone pasture management practice, and to discover tropical grass and legume species that will provide dairy cattle with high quality forage.

## MANAGEMENT

It is difficult to discuss management in general terms as good management must consider economic as well as technical factors and these will vary widely from country to country. As stated elsewhere by W. J. A. PAYNE[5], ' the aim of good management of dairy stock in the tropics is to take all economically justifiable measures that will decrease the " heat load " of the animal or help to " spread " the " heat load " more evenly over the twenty-four hours '. Temperate zone management practices are not based on this premise, and for this reason it is possible that they are unsuited to widespread use in the tropics. This means that it is imperative that in all tropical countries management studies should be actively pursued. It is almost certain that the productivity of dairy cattle everywhere in the tropics can be immediately raised by improved management.

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# *The Use of 2,3,5-Triphenyl-tetrazolium Chloride as a Measure of the Seed Viability of Mexican Grass* Ixophorus unisetus *(Presl.) Schlecht.**

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The standard method of determining the viability of seeds by germination will generally give good results with very little labour. There are times, however, when this process may take too long and when a rapid test is needed as, for example, in the case of seeds having a long dormant period, or responding slowly to after-ripening treatments.

Many methods depend on the detection of specific enzymes or groups of enzymes and here the sensitivity lies in the precision with which the transition from life to death can be detected. Methods based on the presence of diastase, catalase or phenolase enzymes lack precision, but dehydrase and peroxidase reactions appear to be satisfactory. Tests employing the peroxidase reaction are the benzidene and guaiacol tests; malachite green has also been used on peas[1]. 2,3,5-Triphenyl-tetrazolium chloride and sodium biselenite tests are based on the dehydrase reaction and appear to be the most useful.

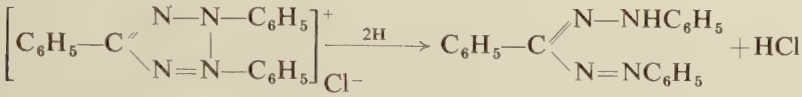
Using the selenium stain G. Lakon developed what he called the topographical method of determining viability, and showed it to be a quick and reliable method to use with common cereals. It was found that in many cases the embryo was only partly stained and hence some criterion of viability became necessary. Lakon assumed first, that those areas of the embryo that stained were the seat of active enzyme reactions and alive, whereas the unstained portion was incapable of growth. In the second place he assumed a seed to be viable only as long as all parts of the embryo essential for the development of the plant and not capable of being regenerated were alive[2]. Thus for each species dealt with it is necessary to know the location and importance of all primordia in the embryo. Seeds with many seminal roots are not affected by the death of some primordia.

In 1941 Kuhn and Jerchel drew attention to the use of tetrazolium salts for quick viability tests, and acting on this Lakon, after trying a number of salts, substituted 2,3,5-triphenyl-tetrazolium chloride for the poisonous selenium salts in his topographical method[2].

Triphenyl-tetrazolium chloride, commonly known as T.T.C., is a pale yellow crystalline powder, very soluble in water. It is advisable to keep it

* Edited by W. J. Badcock.

and the solution in a dark glass bottle as it is light-sensitive and turns dark on exposure[3]. The use of T.T.C. has a distinct advantage over many indicators for testing viability, since it is one of the comparatively few organic compounds that is coloured in the reduced state. In the presence of viable tissue the yellowish T.T.C. forms the insoluble bright red triphenyl formazan by the following reaction.



Colourless Red

VIABILITY TEST METHODS

The procedure for testing viability as outlined by Lakon for maize and followed, with certain modifications, by other workers, consists briefly of the following steps. The grain is soaked overnight and then bisected longitudinally through the embryo; half of each grain is then steeped in a 1 per cent solution of T.T.C. at room temperature for three hours, then removed on to filter paper and checked for results after 24 hours. Seeds are considered viable if the plumule, embryo axis and central portion of the scutellum react to the stain. This method has now been adopted by German seed testing stations for maize and cereals as routine and it is hoped to extend it to legume, cruciferous and certain grass seeds[4]. However, some workers still consider the method too inaccurate for general application and not suitable for small seeds[5,6].

Certain modifications and refinements have been added to Lakon's test. T. Ritvanen using seed of *Phleum pratense* ' scaled ' the seeds initially and found it only necessary to cross-section the seed near the embryo. Staining was carried out in the dark for 19 to 24 hours at 18° to 20°C, but it was found that 5 hours was sufficient time when kept at 45°C. Viable seeds were considered to be those with the embryo wholly stained or with everything but the main root stained[7].

E. O. C. Hyde, working in 1952 with perennial rye grass (*Lolium perenne*) in connection with ' blind seed disease ', sterilized the seed after soaking to prevent bacterial breakdown of the stain. The seeds were only bisected for two-thirds of their length and placed in a 1 per cent solution of triphenyltetrazolium bromide. Various incubation temperatures were tried and different concentrations of the salt. It was found that good staining could be obtained in 5 hours after incubation at 30°C using a 1 per cent solution. The criterion of viability was that the central portion of the embryo axis, from which the lateral seminal roots arise, should react[8].

Using seed of Chewings fescue (*Festuca rubra*), Hyde found that by merely puncturing the pericarp with a dissecting needle good staining could be obtained on the surface of the embryo. The stain could be seen through the translucent lemma but partly stained embryos were dissected out for further examination. In this case the seed was considered viable if the plumule, the embryo axis down to the epiblast and one third of the visible portion of the scutellum reacted to the stain.

L. N. Bass, working with Kentucky blue grass seed (*Poa pratensis*), soaked

the seed after staining with lactophenol solution for two hours to render the lemma and palea more transparent. He used only a 0·05 per cent solution of T.T.C. and found 7·6 per cent of his results were outside the tolerance for seed testing. No indication of having tried a higher concentration is given[9,10].

*Paspalum notatum*, a notoriously difficult seed to test for germination, responds well to this stain if certain modifications are made to the test. R. H. Porter and H. J. Romm found that the viability of *Paspalum notatum* declined if presoaked for more than 3 days at 20° to 30°C. To overcome this the seed was soaked for 16 hours at 20°C, then placed in a Petri dish on moist filter paper at an alternating temperature of 20°C for 16 hours and 35°C for 8 hours over a period of 2 to 4 days. The seeds were then sectioned and soaked in 1 per cent solution of tetrazolium chloride for 8 to 24 hours. In a germination test to check the reliability of the T.T.C. it was found that alternating temperatures of either 15° to 30°C or 20° to 35°C were favourable for the germination of *P. notatum* seed[11].

Tests were carried out in the present experiment to determine the suitability of T.T.C. when applied to tropical grasses as, with the exception of work done by Porter and co-workers on *Paspalum notatum*, most investigations have been limited to temperate species. The seed of Mexican grass (*Ixophorus unisetus*) was chosen, not so much because of its commercial value, but because samples of reasonably high viability were available. The methods of treatment were adapted from work already mentioned in an attempt to find the most satisfactory treatment for this species.

## EXPERIMENTAL PROCEDURE

Three samples of *Ixophorus unisetus* were available. The samples had been harvested at different times and it was suspected that the viability varied from sample to sample. Initial standard germination tests were carried out and germination percentages of 24 per cent, 56 per cent and 71 per cent were obtained. Each sample was then subdivided into three sub-samples of 50 seeds each. The seeds, characteristically attached to the entire spikelet and cartilaginous sterile palea, were first thrashed out by rubbing vigorously between the palms of the hands, and placed in 95 per cent alcohol to float off the extraneous material.

The seeds were then ' dehusked ' by removing the enclosing lemma and palea with forceps. In a trial it was found easier to remove these parts when the seed was dry rather than after soaking for 16 hours, because when the seed was wet the embryos were easily damaged. The dehusked seeds were then soaked in tap water overnight for approximately 16 hours at room temperature of about 23°C.

The soaked seed samples were then treated by sectioning completely in the region of the embryo, by pricking with a dissecting needle (care being taken not to damage the embryo), or received no treatment at all. Thus each sub-sample of a particular germination sample received one of these alternatives. All the samples were then placed in watch-glasses and covered with a 1 per cent solution of T.T.C. and inspected hourly for staining. The watch-glasses were not placed in the dark but out of direct sunlight at about 30°C.

## RESULTS

Staining was noticed on some of the seeds after immersion for half an hour, while all the seeds had been stained after 4 hours. The majority of embryos were completely and brightly stained. A few were less brightly stained and these were also taken as being viable. A very small number was stained in small patches on both the plumule and the radicle while several had the radicle only faintly stained. These two groups were taken as being non-viable. Had every stained seed been included in the estimate of viability, the total would have been grossly exaggerated. The test appeared to be rather more accurate in the case of the samples with a high percentage of viable seeds than in the case of the sample with low viability. The results are presented in *Table 1*.

*Table 1*

| *Germination test %* | *Seed treatment* | *Tetrazolium test %* | *Average %* | *Difference %* |
|---|---|---|---|---|
| 24 | *Cut* | 20 | 22·6 | 4 |
| | *Pricked* | 26 | | 2 |
| | *No treatment* | 22 | | 2 |
| 56 | *Cut* | 58 | 58·86 | 2 |
| | *Pricked* | 58 | | 2 |
| | *No treatment* | 60 | | 4 |
| 71 | *Cut* | 72 | 70 | 1 |
| | *Pricked* | 70 | | 1 |
| | *No treatment* | 68 | | 3 |

## SUMMARY AND CONCLUSION

It was found that *I. unisetus* reacted to the stain T.T.C. which gave a good indication of viability 4 hours after treatment. The criterion of viability appears to be satisfactory judging from the comparison with the germination test. There appeared to be no difference in staining between the various treatments applied to the seed. Although generally considered to be a laborious and skilled process of testing seed viability the T.T.C. test in the case of *I. unisetus* proved to be an extremely easy and rapid method, that could be carried out by untrained laboratory staff.

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# *Weed Control in Sugar Cane with CMU**

A. J. Loustalot†, T. J. Muzik** and H. J. Cruzado††

At the present time most growers of sugar cane in Puerto Rico control the weeds in their fields by using a combination of 2,4-D and hand hoeing. Although 2,4-D is effective against many broad leaved weeds, it does not kill the perennial grasses and, therefore, continued use of this herbicide usually increases the grass infestation by reducing the competition of other weeds. The most common grass weeds in our experimental plots are *Echinochloa colonum* and *Eleusine indica*. The grasses have fibrous roots in about the same soil layers as the cane, and they compete more severely with the cane for nutrients and water than do the broad leaved weeds, which usually have taproots. Also, grasses are harder to control by hand hoeing. CMU (3-*p*-chlorophenyl)-1,1-dimethylurea has been shown to be an effective herbicide against many weeds including grasses[1–3]. Preliminary experiments conducted by A. J. Loustalot, T. J. Muzik and H. J. Cruzado[4] with CMU at three, six and nine pounds per acre in ratoon and plant cane indicated that this material is an effective herbicide for most weeds found in cane fields in Puerto Rico. Under the conditions used, CMU produced no apparent deleterious effects on the cane; there was no chlorosis or stunting, even at the nine pound rate, and there was no statistically significant effect on the yield of cane harvested one year after treatment[5]. In these experiments, CMU was applied in single applications. The most economical rates were between three and six pounds per acre. The herbicide was most effective when applied to freshly prepared soil, free of trash, and before the weeds started growth. In the light of this experience and the promising results obtained, the following experiment with plant cane (*gran cultura*) was conducted, in which split applications of CMU were compared with single applications at a maximum rate of six pounds per acre. It was thought that split applications might extend the period of herbicide effectiveness and thus reduce the amount of hand labour subsequently required for weed control before the cane closed over. The standard plantation weed control practice, consisting of a combination of 2,4-D application supplemented by hand hoeing, was included as a treatment for cost comparison***.

## METHODS AND MATERIALS

The experimental area was planted with cane seed pieces, variety *Mayaguez 336*, on 18 October, 1953, and treatments applied three days

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later. The field was divided into sections 19½ ft wide with drainage ditches in between. Four rows of cane were planted on the ridges in each section. The experiment was designed as a randomized block with eight treatments replicated four times. Individual plots were one section wide and 110 ft long (approximately 1/20 acre). The weeds that developed in the control and treated plots were hoed by hand when the co-operators considered it necessary and the number of man-hours required to weed each plot was recorded.

The CMU was applied in aqueous suspension in one, two, or three applications with intervals of approximately one month between applications. The 2,4-D (diethanolamine salt) was applied three times in aqueous solution, each time at the rate of 2 lb. of active ingredient per acre. The first applications of herbicide were made on 21 October, 1953, when the cane was beginning to shoot but before weeds were visible. The cane was harvested approximately 16 months after planting. In addition to total yield of cane, mill samples were taken and the sucrose content determined.

## RESULTS

The total cost of weed control for all treatments was higher than expected, probably because the cane field was badly flooded on several occasions during the rainy season. As a result, growth was poor and the cane did not close over and suppress the weeds as quickly as expected‡. The comparative cost of weed control is shown in *Table 1.*

*Table 1. Comparative cost of weed control with CMU and 2,4-D in* gran cultura *cane at Hormigueros, P. R., using single and multiple applications*

| *Treatment* | *Amount applied each application* lb./acre | *Number of applications* | *Total chemical applied* lb./acre | *Total man-hrs to hand-hoe** hrs/acre | *Cost of labour to hand-hoe†* $/acre | *Cost of herbicide and its application*** $/acre | *Total cost of weed control* $/acre |
|---|---|---|---|---|---|---|---|
| *Hand-hoe* | 0 | 0 | 0 | 205 | 82·00 | 0·00 | 82·00 |
| *2,4-D* | 2 | 3 | 6 | 72 | 28·80 | 13·06 | 41·86 |
| *CMU* | 3 | 1 | 3 | 90 | 36·00 | 10·60 | 46·60 |
| | 2 | 2 | 4 | 70 | 28·00 | 15·20 | 43·20 |
| | 4 *and* 2 | 2 | 6 | 75 | 30·00 | 21·20 | 51·20 |
| | 6 | 1 | 6 | 96 | 38·40 | 19·60 | 58·00 |
| | 3 | 2 | 6 | 63 | 25·20 | 21·20 | 46·40 |
| | 2 | 3 | 6 | 41 | 16·40 | 22·80 | 39·20 |

* Does not include one extra hand weeding given to all plots by mistake by the collaborator.

† Calculated at the rate of $0·40/hr.

** Calculated at the rate of $3·00/lb. CMU and $1·00/lb. 2,4-D (plus cost of applying them).

The total yield of cane from the plots treated with 4 lb. of CMU per acre followed by a later application of 2 lb. was significantly higher than the control. There was, however, no significant difference in the yield of sucrose. None of the other treatments was significantly different from the control in terms of total yield or in yields of sucrose. These results are shown in *Table 2.*

‡ *Commelina longicaulis* Jacq., the dayflower, was one of the dominant weeds in this experiment.

*Table 2. Yields of sugar cane and sucrose from* gran cultura *sugar cane plots treated with CMU, 2,4-D or hand-hoed only at Hormigueros, Puerto Rico*

| *Treatment* | *Amount applied each application lb./acre* | *Number of applications* | *Total chemical lb./acre* | *Yield of sugar cane* lb./acre* | *Yield of sucrose† lb./acre* |
|---|---|---|---|---|---|
| *Hand-hoe* | 0 | 0 | 0 | 75,500 | 9,500 |
| *2,4-D* | 2 | 3 | 6 | 76,000 | 10,030 |
| *CMU* | 3 | 1 | 3 | 80,150 | 9,615 |
| | 2 | 2 | 4 | 81,100 | 10,035 |
| | 4 *and* 2 | 2 | 6 | 87,000 | 10,695 |
| | 6 | 1 | 6 | 70,000 | 8,855 |
| | 3 | 2 | 6 | 76,000 | 9,815 |
| | 2 | 3 | 6 | 81,200 | 9,525 |

* Yield of cane L.S.D. 4 per cent 9,140, L.S.D. 1 per cent 12,380.

† Yield of sucrose 'F' value not significant.

## DISCUSSION

Split applications of CMU gave better weed control than single applications at the same rate, although the poor growth of the cane in this experiment, due to adverse weather conditions, tended to obscure the results. The chemical weed control plus hand-hoeing gave better weed control at a lower cost than hand-hoeing alone. The 2 lb. rate of CMU applied three times at monthly intervals cost $39·20/acre as compared to the hand-weeded controls which cost $82·00/acre. The 2,4-D appeared to be nearly as effective as the CMU, probably due to the fact that *Commelina longicaulis*, which is very sensitive to 2,4-D, was one of the dominant weeds. These results suggest that a combination of 2,4-D and CMU may give best results where the weed population is mixed grasses and broadleaves.

The yield of the sugar cane was not adversely affected by the CMU in this or previous experiments. In one treatment, 4 lb./acre CMU followed by 2 lb. CMU a month later, the yield of cane was significantly higher than the control. This may have been due to better weed control at a critical period. The yield of sucrose in this treatment was not significantly different, however, from the control.

## SUMMARY

1 CMU was an efficient herbicide for controlling weeds in sugar cane.

2 Split applications were superior to single applications at the same rate. The most economic and most effective treatment was 2 lb./acre of CMU applied three times at monthly intervals.

3 The yield of cane or sucrose was not adversely affected by the application of CMU.

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# *Book Reviews*

## EXPERIMENT IN EXTENSION

ALLAHABAD AGRICULTURAL INSTITUTE. Oxford University Press: London, 1956. 240 *pp.* (illus.) Rs 7

This well prepared little book is interesting even if it does not fulfil the expectations of the title or of the dust cover introduction. It does not give a factual appraisal of the extent, beyond the oft repeated 400 villages, or achievements of this experiment in extension work in India; probably the experiment is too young for such an appraisal though some information about the number, source and turnover of staff, and cost of the experiment could well have been included if the main object was to report the nature of the experiment. Nor can it be considered entirely suitable as a textbook for persons going into the experiment as field workers; some sections are extremely practical for such readers while others seem, to Western eyes at least, too loaded with words and *mystique* to be very comprehensible to a rather humble Gaon Sathi or village companion.

The interest of this book to the outsider lies in its reporting of an effort to put agricultural extension work on a practicable plane for the Indian villager and of the application and adaptation of American extension methods (the Ford Foundation assisted in the project) to Indian conditions. The sponsors of this experiment would be doing a great service to agriculture in all underdeveloped tropical countries if they could as soon as is practicable compile a more factual report of their work for the guidance of others wishing to foster extension.—A.L.J.

## THE MANURING OF SUGAR CANE

D. J. HALLIDAY. Centre d'Étude de l'Azote: Geneva, 1956. 221 *pp.* (illus.)

This second book of a series has certainly maintained the high standard achieved in the first. All who have been concerned with producing it are to be congratulated. The author has succeeded in reducing the vast amount of available information on sugar-cane growing to reasonable proportions and has presented it in a very readable form.

The selection of photographs has been well done and represents a very high standard of photography. Diagrams and tables have been well prepared to provide essential information. The maps leave room for criticism; there are rather more than necessary, and in several instances they are inadequately marked with place names or geographical features to define locations of sugar areas.

The publishers are to be congratulated on the high standard they have achieved, in binding, printing and arrangement of material. This book should be read by every student studying sugar-cane growing, and the extensive bibliography will be valuable to research workers.—W.J.B.

## BIOLOGY OF ROOT-INFECTING FUNGI

S. D. Garrett. Cambridge University Press: London, 1956. xi + 293 *pp.* 30*s*

In this book the author both summarizes research on root-infecting fungi over the last 25 years, and presents his own views on the modern approach and the trends to be followed in the future. It is a most comprehensive book. After a short introduction, mainly dealing with the biological control of root disease, and a chapter on the fungus flora of the soil, the author goes on to discuss the four topics of the parasitic growth habit, the saprophytic behaviour of root-infecting fungi, epidemiology, and the principles of root-disease control. There are also chapters on dormancy and the relation of root-surface and rhizosphere microfloras to root infection.

Although many of the fungi in the soil do not cause disease in plants, they are all part of the ecological surroundings within which the root-infecting fungi must live, and compete for food materials. As such their study is of paramount importance in the investigation of root diseases. The author criticizes the current methods of studying the fungi of the soil, and proposes the more rational approach of grouping the fungi according to the various substrates they utilize. Thus there are the sugar fungi, the cellulose decomposers, those that use lignin and the predatory fungi. The fact of succession, the utilization of a substrate by first one and then another fungus is well known, and a study in substrate relationships using the grouping above will help to clarify these ideas and lead to better techniques for the detection and isolation of fungi from the soil.

The book is completed by a bibliography of some 500 references and an index through which this may easily be reached by way of the text. Altogether this volume is very readable and should become a useful work of reference on the shelf of every plant pathologist.—R.F.B.

## PRINCIPLES OF FUNGICIDAL ACTION

J. G. Horsfall. Chronica Botanica, Waltham, Mass.; Wm. Dawson, London, 1956. xx+280 *pp.* (illus.) $6.50

This book should be of great interest to all those who deal with fungicides in their work, whether they are concerned with seeking new substances for the protection of crops or are using already proven fungicides and wish to know something of why and how they are effective. It is not, perhaps, too easy a book to read for the general worker, but it will be a very useful reference book into which he can dip for help on a particular problem. This will be greatly facilitated both by the excellent bibliography of nearly 700 references and the general and author indices.

The book can be divided into two main sections. After an introductory chapter the next three deal with the measurement of fungicidal action and protection, and the mobilization of a residual protectant. These are followed by one chapter on permeation into the fungus and two on the physical effects on the fungus, of which the first deals with the disruption of the cellular organization and the second with the effects on mitosis, morphology and growth.

The second part of the book deals with the chemical effects of fungicides. The first two chapters, on the effects on the metabolism of the fungus and the chelation of needed metals, are written from the standpoint of the fungus, and the next five, on the action of metals, sulphur, organic sulphur compounds, quinones and other ketones, and heterocyclic compounds, are written from the point of view of the compounds themselves. The final chapter deals with the new and rapidly expanding subject of the chemotherapy of plant diseases.—R.F.B.

## THE CHEMISTRY AND MODE OF ACTION OF PLANT GROWTH SUBSTANCES

R. L. Wain and F. Wightman (*Eds*). Butterworths Scientific Publications: London, 1956. xi+312 *pp*. (illus.) 55*s*

This book contains the papers read at a Conference on Plant Growth Substances held at Wye College in July 1955, attended by leading workers in this field, from Europe and the U.S.A. The object of the Conference was to bring together these workers and give them an opportunity to present and discuss their results on the more fundamental aspects of plant growth substance investigations. The editors must be congratulated in making available to other workers the Proceedings of the Conference in book form.

The papers have been grouped into four sections. The first, embodying seven papers, is entitled ' Natural Auxins ' and deals essentially with techniques of isolation and bio-assay of naturally occurring plant growth substances and results obtained after analysis of various plant organs. The paper by J. P. Nitsch of Harvard University is an excellent introduction to the technique of paper chromatography as applied to the isolation and identification of auxins. Two papers may be mentioned for their special interest; the role of indole compounds in photo-induced plants by A. J. Vlitos, who summarizes the present position with respect to flowering, and a paper by S. A. Gordon on the biogenesis of natural auxins.

Section II, ' Chemical Structure and Biological Activity ', consisting of 10 papers, will appeal to those workers interested in the relation of molecular structure of growth-active and allied compounds to penetration and degradation within plant tissues. In addition, F. C. Steward and E. M. Shantz present an interesting paper on their latest work on chemical induction of growth in tissue cultures. The seven papers of the third section, ' Metabolism and Mode of Action ', are concerned with the effect on subsequent activity of the tissues of exogenous applications of auxins.

The fourth section, ' Application of Kinetics to Auxin—Induced Growth ', contains two controversial papers, one by T. A. Bennet-Clark of London and the other by J. Bonner and R. J. Foster of California, on a subject which has only recently received attention, but they do illustrate the essential value of the Conference in that members of two research schools were able to meet and discuss their differing hypotheses. In conclusion, it might be stressed that this is not a book for the practical agriculturalist but it is an essential one for workers engaged on fundamental growth substance research.—R.N.

## THE STORAGE OF SEEDS FOR MAINTENANCE OF VIABILITY

E. Biasutti Owen. Commonwealth Agricultural Bureaux: Farnham Royal, Bucks., 1956. 81 *pp.* 20*s*

This book constitutes one of the most valuable contributions to the literature of agricultural science in recent years, more particularly so, perhaps, for research workers and others concerned with the storage of valuable seed in the humid tropics. The author has arranged and presented information on different aspects of seed storage in separate chapters. This makes reference easy and required information can be obtained quickly. There are a number of useful tables providing tabulated information relative to such matters as the influence of moisture content, temperature and time on seed viability.

The separate chapter by T. Ashton on genetical aspects of seed storage provides information on a subject of particular importance to plant breeders. There is a most excellent summary of information given on pages 52 and 53 under the title of ' Conclusions '. The list of references cited provides ample scope for more extensive reading on this subject. This book presents in a concise form information which hitherto has been difficult to obtain, except by reference to numerous publications not always readily available. —W.J.B.

## AN AGRICULTURAL NOTE BOOK

T. A. Phillips. Longmans Green: London, 1956. 218 *pp.* 5*s*

With the assistance of colleagues in the Nigerian agricultural departments, T. A. Phillips has set out to do for Nigeria what Primrose McConnell so long ago did for British agriculture, and C. Wood later for tropical agriculture as a whole. In this he has succeeded admirably. The Note Book is an excellent compendium of information skilfully compressed. It is stoutly bound and of handy size. It should be invaluable in Nigeria, especially to junior agricultural staff and English-reading farmers; but it will also find interested readers further afield. Other tropical territories, please copy !—G.B.M.

## THE NEW GOLD COAST FARMER, Vol. I, No. 1, August 1956

Gold Coast Dept of Agriculture. Annual subscription: Gold Coast 4*s*, external 5*s*

This ' new ' publication is really a resumption of the old *Gold Coast Farmer*, production of which was suspended on the outbreak of war in 1939. Its aim, as set out in an editorial, is to provide reading matter principally for the junior agricultural staff of government, the literate farmer, and interested persons overseas. It thus attempts a somewhat unusual level, somewhere between a research journal and a farmers' magazine. This level is well hit off in the opening number, which includes articles, such as those on problems of cocoa growing and agricultural history, which are intelligible to any layman, while a paper on fertilizer trials provides tougher reading. The historical article appears a little muddled, stating

in one place that maize was introduced by the Portuguese (the normally accepted view), while suggesting elsewhere that it was grown at the time of Carthaginian visits and in the 13th century. It will be interesting to see whether this journal can maintain the level it has set itself, and all success may be wished to the venture.—G.B.M.

## HANDBOOK FOR CO-OPERATIVE PERSONNEL IN THE CARIBBEAN

W. J. W. Cheesman. FAO and Caribbean Commission: Trinidad, 1956. 252 *pp.*

A successful handbook that is intended to instruct as well as inspire workers in co-operative departments is most difficult to prepare. Not only do the details of instruction, such as the penultimate chapter of this book on the Settlement of Disputes, dilute the inspirational message but the whole thesis of fostering co-operation proposes a paradox. The guiding co-operative principle is mutual self-help, and self-help cannot be fostered by lavish extraneous help. This paradox is most important in the Caribbean where centuries of paternalism have created an atmosphere not congenial to self-help. Many well meaning efforts to stimulate co-operation in the Caribbean have resulted in the governments becoming the new patrons and the people remaining even more convinced that it is not their own responsibility to help themselves.

Only a writer immersed and expert in his subject could provide a really useful handbook under this title, and it is greatly to the author's credit that this publication appears likely to be so. He has struck a fine balance between the message and practice of successful co-operation: he has been clear and emphatic about what is required of co-operators as well as what benefits can be expected from co-operation. The reviewer would have liked to see W. J. W. Cheesman's wide experience applied in one chapter to a critical analysis of the possibilities of co-operation in the Caribbean: are some countries more suitable than others? Are some fields of co-operation more promising than others? And so on. But perhaps such a chapter would be outside the scope of this Handbook.

The Handbook is excellently produced in vari-type and is robustly bound to serve as a constant companion of co-operative officers, particularly those in the field. Some of the tables are annoyingly incomplete but the bibliography at the end of each chapter will prove to be a godsend to Co-operative Departments in the area.—A.L.J.

## THE GOLD COAST COCOA FARMER: A PRELIMINARY SURVEY

P. Hill. Oxford University Press: London. 1956. viii – 139 *pp.* illus. 16*s*

This is one of the new 'paper-backs', an unsatisfactory but perhaps necessary type of binding, which has enabled the price to be kept down and the volume to appear in about twelve months from the date of the foreword. The content of the report compensates for the defect. In contrast to the £70,000 survey 'Nigerian Cocoa Farmers' reviewed in the January issue,

this survey was financed by a grant, from the West African Institute of Social and Economic Research, which allowed ' for the employment of no more than one full-time worker '. A mass of new information was collected by questionnaire and interview with the willing assistance of the agricultural co-operatives, ten widely distributed societies being selected. Three main aspects are dealt with, the employment of labourers, the ' pledging ' (a type of mortgage) of cocoa farms, and farmers' income and expenditure. The book is ' a collection of separate socio-economic reports ', and makes no claim to be a comprehensive review of cocoa farming. It is a clear and easy exposition without pretence or padding and throughout the author gives her own appraisals of the validity of the sample or the methods used, and of the reliability of the data.

In addition to the statistical approach, documentary research and consultations provided material for a historical review of pledging and for a final chapter on the early history of Gold Coast cocoa up to 1925. There is a curious omission of any reference to Tettey Quarshie who has been built up into a national hero as the founder of the cocoa industry. A table of exports gives figures from 1900 to 1938 only and one of cash received by the farmers gives figures for 1926–7 to 1935–6 only: up-to-date figures for the former are published and for the latter the figure has been regularly compiled in the Department of Agriculture. These are minor criticisms. The whole report is a good example of what can be done in spite of slender resources, and is a very valuable contribution to the present deplorably small store of knowledge of the economic and social aspects of Ghana agriculture.—W.H.B.

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Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the 1939–45 war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

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These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

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